CUTTYHUNK HARBOR

GOSNOLD

MASSACHUSETTS

DESIGN MEMORANDUM
ON
PROJECT MAINTENANCE
CONSTRUCTION OF STONE DIKES
REPAIRS TO SOUTH JETTY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

26 AUGUST 1963

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

26 August 1963

SUBJECT: Design Memorandum on Cuttyhunk Harbor, Gosnold, Mass.

TO: Chief of Engineers
ATTN: ENGCW-OM
Washington 25, D. C.

1. Reference is made to Chief of Engineers teletype ENGCW-OM 606 dated 21 November 1962 which authorized a study and design memorandum on Cuttyhunk Harbor, Mass. The study has been made and 10 copies of the Design Memorandum are inclosed.

2. The existing project at Cuttyhunk Harbor provides for a 10-foot deep channel with two entrance jetties and a 10-foot deep 16 acre anchorage. It was authorized in 1937 and completed in 1939 at a Federal cost of $27,167. Federal maintenance costs have been $411,338 to date. Local interests have contributed $11,643 for new work and and $101,820 in cash and construction for maintenance. This harbor is used by a small local fleet, and for refuge and overnight stops by many recreational and small fishing craft, and also as a rescue boat station by the U. S. Coast Guard. Additional maintenance work is now needed.

3. The inclosed design memorandum discusses studies to select the best means of maintaining the Federal project. A plan to construct dikes to preserve the beaches that protect the harbor is recommended. Early construction of Phase 1 to prevent breaches that are imminent is recommended at a cost of $340,000. Phase 2, possible future additional dike construction if it becomes necessary, would cost an additional $210,000.

4. It is proposed to request funds for construction of Phase 1 of this maintenance work in FY 1965. Phase 2 will be scheduled at some future fiscal year if it becomes necessary.

5. Approval of the plan for maintenance of Cuttyhunk Harbor, Massachusetts as described in the inclosed design memorandum is recommended.

1 Incl (10 cys)
Design Memorandum

P. C. HYZER
Brigadier General, USA
Division Engineer

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham 54, Mass.

NEDGW 26 August 1963

DESIGN MEMORANDUM ON CUTTYHUNK HARBOR, GOSNOLD, MASS.

(REPAIRS TO JETTY - CONSTRUCTION OF STONE DIKES)

PERTINENT DATA

Project Authorization: 26 August 1937.

Project Document: House Document No. 81, 75th Congress, 1st Session.

Date of Survey Report: 29 May 1936.

Date of Completion of the Authorized Project: 1939.

The Present Problem: The Canapitsit Beach barrier, which protects the project from the south, has again deteriorated to a point where it is in danger of breaching. The Copicut Neck Beach Barrier, which protects the inner harbor from the northwest, has also eroded and is in danger of breaching. In addition, the south jetty is in bad state of repair.

Proposed Solution: Construct stone dikes at Canapitsit and Copicut Neck Beaches to protect and preserve these barriers and reduce shoaling. Reconstruct and extend the south jetty. It is proposed to do this work in two phases. In addition, further maintenance of the channel, anchorage and north jetty should be continued.

First Cost of Project: Total cost is $550,000.

Phase 1.	Easterly half of Canapitsit Beach Dike and southerly half of Copicut Neck Beach Dike	$340,000
Phase 2.	Westerly half of Canapitsit Beach Dike and south jetty and northerly half of Copicut Neck Beach Dike	210,000
		$550,000

<u>Annual Charges</u>: $35,400, of which $14,000 is for maintenance.

<u>Benefits</u>: Prevention of loss and damages to vessels using harbor for refuge. In addition, benefits to the local U. S. Coast Guard base, and to local and transient fishing and recreational fleets.

<u>Schedule for Accomplishment</u>: Complete planning and start and complete contract work on Phase 1 in FY 1965. Phase 2 would be scheduled for some future fiscal year if it becomes necessary.

<u>Design Features</u>: Maintenance of the 10' channel and anchorage, and of the north jetty is not required at present. Repairs to south jetty and extension: 450' with 5' crest at elevation +7. Canapitsit Beach Dike: 1300' with 5' crest at elevation +10, 700' with 10' crest at elevation +12 and 20' apron, and 600' with 6' crest at elevation +12 and 300' of 10' apron. Copicut Neck Beach Dike: 600' with 5' crest at elevation +10 and 10' apron, and 600' with 6' crest at elevation +12 and 10' apron.

<u>Design Factors</u>:

Tides: Mean range is 3.4'; Spring range is 4.2'; Design tide for 1-year frequency is 6'.

Waves: 4.5' at south jetty; 4.7'-6.5' at Copicut Neck Beach; at Canapitsit Beach waves of 5'-11' allowed in design, although only the maximum supportable by available depths may occur.

Stone Sizes: Armor stone sizes vary for various sections of the structures; minimum 0.5-4.0 tons; maximum 2.0-10.0 tons.

PROJECT AUTHORIZATION

1. The existing project is the only Federal navigation project that has been authorized for Cuttyhunk Harbor. Authorized by the River and Harbor Act of 26 August 1937, it provides for an entrance channel generally 75 feet wide and 10 feet deep at mean low water from the outer harbor to the westerly terminal in Cuttyhunk Pond; an anchorage in the inner harbor, 10 feet deep at mean low water, 900 feet long and 800 feet wide; and for maintenance of the jetties which had been constructed by the Commonwealth of Massachusetts. The project is described in House Document No. 81, 75th Congress, 1st Session.

2. The new work in the Federal project was completed in 1939 at a cost of $38,811.23, of which $11,643.37 was contributed by local interests. The requirements of local cooperation specified in the project document provided that,

> "local interests contribute 30 percent of the first cost, but not to exceed $19,500, and furnish, free of cost to the United States, suitable spoil-disposal areas for new work and subsequent maintenance."

These requirements were fully complied with at the time of project construction. Town officials have given assurances that future spoil disposal areas will be provided when needed.

3. Project maintenance commenced in 1939 by expenditure of $17,660.50 for repairing the jetties and partial restoration of the barrier beach which protects the channel from the south. Channel maintenance dredging was undertaken in 1947 at a cost of $18,812.18. In 1949 the channel was redredged at a cost of $50,128. Part of the barrier beach was rebuilt in 1949 and the remainder was completed in 1951, at a cost of $268,012, of which $50,000 was contributed by the Commonwealth of Massachusetts. Additional channel dredging was accomplished in 1952 at a cost of $30,035. Later, in 1954, the barrier had breached again and restoration work was initiated, but had to be abandoned due to hurricane damage and was resumed in 1955. The Federal cost of this work was $49,110. In addition, the Commonwealth of Massachusetts had shared in the project by dredging about 40,000 cubic yards for placement on the barrier at an estimated cost of $51,820, in lieu of a cash contribution. Subsequently, maintenance dredging of the channel was again undertaken in 1962 at a cost of $35,855. In 1963 boulder removal from the turning basin cost $23,903. The

total Federal expenditures for maintenance of the project have amounted to $411,388, including $18,000 for the present study of maintenance and this design memorandum. In addition, the Commonwealth of Massachusetts has expended about $101,820 for maintenance of the barrier beach.

INVESTIGATIONS

4. Project Document. - Investigations made in connection with the survey report of 29 May 1936, submitted to Congress on 12 August 1936 and printed in House Document No. 81, 75th Congress, 1st Session, included a hydrographic survey of the entrance channel and the inner harbor, determination of the nature of bottom materials by probing in the same locations, and topography of the adjacent shores, made on 16-22 April 1936.

5. Subsequent to Project Document. - Frequent hydrographic, probing and topographic surveys have been made of various parts of the harbor and its adjacent shores since project authorization. The dates, character and coverage of these surveys are listed below:

1938 29 June - 1 July, before dredging, entrance channel and inner harbor, probings in anchorage; Sept., Oct. & Dec., before dredging, Canapitsit Beach, jetties, entrance channel and inner harbor, probings on Canapitsit Beach to west of south jetty; 1-5 Oct., before repairs, north jetty; 13-16 Dec., after dredging, anchorage.

1939 4 Jan., before construction, dike at Canapitsit Beach; 10 Jan., before dredging, borrow area north side of Canapitsit Beach west of south jetty; 13-16 Jan., after dredging sweepings and probings, turning basin; 17 Jan., borrow area not used, south side of Copicut Neck spit; 17-27 Jan., after dredging, channel and turning basin; 26 Jan., after dredging, borrow area north side of Canapitsit Beach west of the south jetty; 27 Jan., after construction, dike at Canapitsit Beach; 27-31 May, examination, southerly area of Cuttyhunk Pond or inner harbor; 8 June, after dredging, turning basin.

1941 9, 10 & 15 Jan., examination, Canapitsit Beach, entrance channel, jetties and southerly tip of Copicut Neck spit, and Copicut Neck Beach.

1947 13 March, examination, channel and anchorage, Canapitsit Beach and breach; 1 & 2 Oct., after dredging, entrance channel.

1948 28 Oct. - 23 Nov., examination with probings, Canapitsit Beach and breach, Copicut Neck spit and offshore area to east, inner harbor areas to east and to west of the anchorage.

1949 27-29 April, examination, Canapitsit Beach and offshore area to south, and entrance channel; 6-11 July, before dredging, Canapitsit Beach and offshore area to south, outer harbor in vicinity of breach, entrance channel and area east of anchorage in inner harbor, and jetties; 10-12 Aug., during construction, Canapitsit Beach and offshore area to south in vicinity of south jetty, and entrance channel; 7-11 Sept., Canapitsit Beach and offshore area to south, between dredging at entrance channel with probings; 18-21 Oct., during construction of protective barrier, Canapitsit Beach and offshore area to north and to south; 18-23 Dec., after dredging, Canapitsit Beach and offshore area to south, entrance channel and area in inner harbor to east of the anchorage.

1950 22-25 March, condition survey, Canapitsit Beach barrier and offshore area to south, and entrance channel; 5-11 Oct., examination, Canapitsit Beach and breach area, and entrance channel and jetties.

1951 8-10 Aug., after construction, north jetty and Canapitsit Beach barrier extension.

1952 25-26 Feb., examination, entrance channel; 12-13 June, after dredging, entrance channel at outer and inner ends.

1954 29-30 March, examination, northside of Canapitsit Beach and entrance channel in vicinity of south jetty; 31 March, condition of Canapitsit Beach barrier; 12-14 April, examination, outer harbor in vicinity of entrance with probings, entrance channel, and inner harbor at and near the channel; 21 Sept., examination, outer harbor in vicinity of entrance, channel and anchorage, and Canapitsit Beach.

1955 22-23 April, examination after dredging and construction, Canapitsit Beach, entrance channel, and areas east and west of south jetty.

1960 13 June, condition of north jetty; 13-21 June, condition survey of entrance and inner channels, turning basin and anchorage.

1962 10-20 April, examination, Canapitsit Beach, channels, turning basin and anchorage, and tip of Copicut Neck spit; 12 Sept., pre-dredging, inside half of entrance channel and turning basin; 23-24 Oct., after dredging, inside half of entrance channel and turning basin with probings; 20-29 Nov. & 3-4 Dec., condition surveys for present design memorandum, Canapitsit Beach and offshore areas to south and to northeast, south jetty, and Copicut Neck Beach.

6. Preliminary Examination - 14 July 1947. - Under the authority of the River and Harbor Act of 24 July 1946 a favorable preliminary report was prepared recommending that a survey be made. A public hearing was held on 20 November 1946 at Cuttyhunk in connection with this report. It was attended by about 20 persons, including State and town officials, representatives of the U.S. Coast Guard and interested citizens. It was requested at the hearing that means be found for the preservation of the Canapitsit Beach barrier, that the existing anchorage area be enlarged and that a small anchorage be provided west of the turning basin.

7. Survey Report - Not Completed. - On 23 October 1947 the Chief of Engineers authorized a survey report. Work accomplished in connection with this survey report has included a preliminary analysis of sources of supply of beach materials, rates of supply and loss, manner and movement of materials, method of modifying rate of loss and effect of method, design characteristics and a plan of investigation. A hydrographic, topographic and probing survey was made on 28 October to 23 November 1948.

8. Report on Proposed Procedure - 4 May 1949. - A brief and rapid study was made proposing emergency maintenance measures. This study included consideration of alternative plans for strengthening the barrier to protect the channel, a plan to relocate the channel 800 feet northward, a breakwater to close the breach, and two additional anchorage areas at the westerly portions of the inner harbor.

9. Present Design Memorandum. - Investigations undertaken in connection with the present design memorandum include the hydrographic and topographic surveys of 20-29 November and 3-4 December 1962, shown on Plates 2 and 3, inspections of the study area and conferences with local interests, studies of winds and storms, waves, tides and currents, shoreline and offshore depth changes, materials, and analysis of harbor shoaling, which are discussed

in the Appendix. The Appendix also includes discussion of design criteria for the proposed structures at Canapitsit and Copicut Neck Beaches, and economic studies. The studies have included analysis of vertical aerial photographs taken in 1944, 1946, 1948, 1951, 1954, 1955, 1961 and 1962, oblique aerial photographs taken in 1937, 1946, 1947, 1949, 1957, 1960 and 1963, and ground photographs of 1962. Additional investigations made for the present design memorandum considered existing harbor facilities, normal activity by local and transient fleets, and use of the harbor for refuge under storm conditions.

LOCAL COOPERATION REQUIRED AND VIEWS OF LOCAL INTERESTS

10. Local cooperation required by the authorizing legislation is set forth in Paragraph 2 of this memorandum. Local interests had complied with all requirements, inclusive of a cash contribution, at the time of project construction and town officials had given assurances that future spoil disposal areas will be provided when needed. These requirements have also been met at the times of past project maintenance, and are expected to continue to be met as the need arises in the future.

11. Various alternative plans, as shown on Plate 8, were discussed on 5 April 1963 at a conference in Cuttyhunk with a group of interested persons. It was the consensus at the conference that the present location of the entrance to the inner harbor appears to be the most convenient and safe location and that preservation of the Canapitsit Beach barrier is mandatory. Relocation of the channel would result in a more exposed entrance and thus render the harbor difficult to use during storms from certain directions.

12. The views of the U.S. Coast Guard, as expressed by the Chief of the local station, were in favor of maintaining adequate access to the inner harbor.

13. The Commonwealth of Massachusetts has not presented any official views on the proposed project.

14. In connection with the proposed project maintenance plan, local interests should provide without cost to the United States all lands, easements, rights-of-way and suitable spoil disposal areas for the construction and maintenance of the project when and as required. They should also hold and save the United States free from damages that may result from the construction works and maintenance of the project.

LOCATION OF PROJECT AND TRIBUTARY AREA

15. Cuttyhunk Harbor is located near the eastern end of Cuttyhunk Island, which is the most westerly of the Elizabeth Islands. The Elizabeth Islands constitute the town of Gosnold, Massachusetts, and extend 14 miles southwesterly from Woods Hole, Cape Cod, Massachusetts, separating Buzzards Bay on the north from Vineyard Sound on the south. Cuttyhunk Harbor opens into Buzzards Bay and consists of an outer and inner section. The outer harbor has a usable area of about 50 acres varying from 10 to 16 feet in depth. It is afforded some protection from the south by Canapitsit Beach and Island, but is exposed to the north, with the exception of limited shielding offered by Penikese Island. The outer harbor connects with Vineyard Sound through Canapitsit Channel which lies between Canapitsit and Nashawena Islands, although Quicks Hole Channel to the east of Nashawena Island is preferred by navigators. The inner harbor, or Cuttyhunk Pond, covers an area of more than 100 acres with depths ranging from 1 to 14 feet below mean low water. A channel with an authorized depth of 10 feet leads between jetties from the outer harbor to a 16-acre 10-foot deep anchorage in the inner harbor. The inner harbor is landlocked and the 10-foot anchorage provides good shelter, except during hurricanes. Cuttyhunk Harbor is located about 14 miles south of New Bedford Harbor, 14 miles southwest of Woods Hole Harbor, 22 miles southwest from the western end of the Cape Cod Canal, and 28, 30 and 35 miles east of the harbors at Newport, Point Judith and Block Island, Rhode Island, respectively.

16. Cuttyhunk Island is the principal population center of the town of Gosnold, the other Elizabeth Islands being practically uninhabited. The town permanent population varied from about 60 in 1936 to 136 in 1940, to 56 in 1950 and to 66 in 1960. The population is greatly increased during the summer by summer residents, vacationists and tourists. The principal occupation of the area includes fishing, lobstering, and the entertainment of summer visitors, including a large number of transient yachtsmen and other boat owners. Cuttyhunk lies close to the route traversed by boats using the Cape Cod Canal, Buzzards Bay and Vineyard Sound, and is used for refuge and night stop-over by small boats sailing from Long Island Sound to the Cape Cod Canal.

PROJECT PLAN

17. The existing project was authorized in 1937, constructed in 1939, and has been maintained frequently to the present time.

The most recent maintenance has consisted of dredging at the entrance channel and at the turning basin in 1962, and boulder removal from the turning basin in 1963. Additional maintenance of the channel and anchorage areas is not required at present, since they are at project dimensions, as shown on Plates 2 and 3.

18. The existing project also provides for maintenance of the entrance jetties. The north jetty appears to be in fair condition and need not be maintained at the present time. The south jetty, however, is badly damaged and requires major reconstruction. In addition, shoreward extension of the south jetty is desireable to intercept more effectively westward movement of littoral material along the north side of Canapitsit Beach.

19. To maintain the entrance channel at its present location, without frequent and costly dredging, it is essential to protect and preserve the Canapitsit Beach barrier. Alternative methods of protecting this barrier have been considered, as discussed in the Appendix and shown on Plates 2 and 3. The project maintenance plan considered most feasible to accomplish this purpose is referred to as Plan I, shown on Plate 1 and described below.

20. The selected plan for project maintenance consists of the following items:

a. Maintain the present entrance channel, turning basin and anchorage area to the dimensions and 10-foot depth authorized; no maintenance dredging is required at the present time.

b. Repair the entrance jetties; no repairs are required for the north jetty at the present time. The south jetty should be reconstructed by placement of stone, of 0.5 to 2.0 tons weight, to form a 5' crest at elevation +7 above mean low water, with 1 on 1.5 side slopes, and should be extended about 150' shoreward to the same dimensions.

c. Construct and maintain stone dike on Canapitsit Beach to protect and preserve the barrier. The westerly 1300' of dike to have a 5' crest at elevation +10 with 0.5-2.5 tons stone; the central 700' to have a 10' crest at elevation +12 and a 2'x20' apron with 1.0-10.0 ton stone; and the easterly 600' to have a 6' crest at elevation +12 and 300' of 2'x10' apron with 0.5-2.5 ton stone. All side slopes to be 1 on 1.5.

d. Construct and maintain a stone dike on Copicut Neck Beach to protect and preserve that barrier. The southwesterly 600' of dike to have a 5' crest at elevation +10 and a 2'x10' apron with 0.6-2.5 ton stone; and the northeasterly 600' to have a 6' crest at elevation +12 and a 2'x10' apron with 1.3-3.5 ton stone. All side slopes to be 1 on 1.5.

21. The proposed structures have been divided into nine component sections that have generally different design characteristics. Typical cross-sections for each section are shown on Plate 1. All side slopes are 1 on 1.5. Where possible a sandtight core of quarry run stone, assorted sizes is to be included. Armor stone, AA and A, is to be placed to interlock and on a layer of crushed stone of 2.5" maximum size unscreened, generally 0.5' or 1.0' in thickness, as shown, except where placed on core or underlayer stone. The principal structure dimensions and characteristics are tabulated below:

	Section								
	1	2	3	4	5	6	7	8	9
Length (feet), dike	600	600	800	500	450	200	500	500	100
" apron	600	600	-	-	-	200	500	300	-
Width (feet), crest	5	6	5	5	5	10	10	6	6
" apron	10	10	-	-	-	20	20	10	-
Elevation, crest	+10	+12	+10	+10	+7	+12	+12	+12	+12
" base	+6.5	+7	+6	+4	+4	+4	+2	+6	+8
" toe	+6.5	+7	+4	+4	+4	+4	+2	+6	+6
Thickness (feet),									
armor AA	-	-	-	-	-	6	7	-	-
" armor A	3.5	5	3	3.5	3	4	5	3.5	3
" underlayer	1.5	2	1.5	1.5	1.5	2	2	1.5	1.5
Minimum stone weight									
(tons), armor AA	-	-	-	-	-	2.5	4	-	-
" armor A	0.6	1.3	0.5	0.6	0.5	1.0	1.5	0.6	0.5
" underlayer	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1
Maximum stone weight									
(tons), armor AA	-	-	-	-	-	5	10	-	-
" armor A	2.5	3.5	2	2.5	2	3	4	2.5	2
" underlayer	0.2	0.3	0.2	0.2	0.2	0.3	0.4	0.2	0.2

22. The various sections of the proposed structures are designed for minimal initial construction, with limited trenching-in of the new structure. Armor stone has been selected to provide

reasonable stability for conditions anticipated in the future. Armor stone of 2.5 to 4 tons would be adequate for breaking waves of 9 to 11 feet in height. The range of stone sizes from 0.5 to 1.5 tons minimum is adequate for breaking waves between 5 and 8 feet in height, which could be supported if the bottom of the fronting beach near the toe of the structure erodes to below 0 to 4 feet below mean low water, respectively. (In the event that erosion of Canapitsit Beach is excessive in the future and bottom depths near the toe of the structure are below those allowed for at present, heavier stone should be used for maintenance of the structure.)

DEPARTURES FROM PROJECT DOCUMENT PLAN

23. The principal departure of the proposed project maintenance plan from the project document plan consists of provision for stone dikes to protect and preserve the barriers at Canapitsit and Copicut Neck Beaches. These works are considered essential for maintenance of the navigation project at Cuttyhunk Harbor. Precedence for barrier protection in connection with project maintenance at his harbor lies in the 1939 construction of a sand dike on Canapitsit Beach, in the recommendations of the 4 May 1949 report and subsequent construction of a protective barrier with barges, car floats and sand fill.

GEOLOGY

24. Cuttyhunk Island is of glacial origin. It is probable that the barrier beaches forming the perimeter of the inner harbor are spits or tombolos formed through erosion of higher ground on Cuttyhunk Island, Copicut Neck and Canapitsit Island. Materials on the island comprise of sand, gravel and boulders. Littoral drift is small, since erosion of the bluffs around the island is resisted by the natural armor of boulders remaining from previous erosion. The barrier beaches are generally composed of small stones and gravel.

OTHER PLANS INVESTIGATED

25. Several generalized plans were given consideration, including channel relocation schemes, as shown on Plate 8. The alternative methods of protecting Canapitsit Beach that were studied in detail are all variations of the generalized Plan C. They all include reconstruction and shoreward extension of the south jetty, a stone dike to protect Copicut Neck Beach, and continued future maintenance of the existing channel and anchorage and of the north jetty. The variations in these methods are described briefly below:

Plan I. (Recommended). High stone dike with apron on top of barrier.

Plan II. High stone breakwater with apron on south side of barrier, near shore.

Plan III. Low stone dike on top of barrier and low stone breakwater with apron near shore on south side of barrier.

Plan IV. Low stone dike on top of barrier and low stone breakwater with apron offshore to south of barrier.

26. Other generalized solutions given secondary consideration are shown on Plate 8 and are described briefly below:

Plan A. (Existing project maintenance). Channel at present location and sand dike on Canapitsit Beach with additional barges or similar measures.

Plan B. Channel at present location and stone dike along the channel generally to west of south jetty. This plan would not prevent breaching of the easterly section of Canapitsit Beach.

Plan C. (Variations of this plan studied in detail). Channel at present location, sand dike at Copicut Neck Beach and extensive stone dike on Canapitsit Beach.

Plan D. Relocation of entrance channel across Copicut Neck Beach with jetty and sand dikes.

Plan E. Relocation of entrance channel across Copicut Neck Beach with jetty and sand dikes, and closure of present entrance.

Plan F. Relocation of entrance channel across lower Copicut Neck spit with jetties, and closure of present entrance.

Plan G. Relocation of entrance channel across upper Copicut Neck spit with jetty.

Plan H. Relocation of entrance channel across upper Copicut Neck spit with jetty, sand dike on Copicut Neck Beach and closure of the present entrance.

27. Some of the relative advantages, disadvantages and other aspects of selected plans are discussed in the Appendix. Selection of Plan I as the most desirable means of maintaining the

Federal navigation project at Cuttyhunk Harbor was, in part, based on the following considerations:

a. The proposed plan provides for minimum deviation from the existing project.

b. The present location of the entrance channel is the least exposed and appears to be the safest and most convenient approach to Cuttyhunk Harbor, with which local boatmen are accustomed and prefer.

c. The present entrance is nearest to Canapitsit Channel with access from Buzzards Bay to Vineyard Sound.

d. The U.S. Coast Guard boat house is located just inside the inner harbor and has direct access to the present entrance channel without traversing through the inner harbor.

e. The outer harbor is relatively protected and affords a generally safe approach to the entrance channel. The outer harbor has the added advantage of providing extra anchorage space which is protected from most storms and can be used by deep draft vessels and by smaller boats when the inner harbor is filled to capacity.

f. Protective works to preserve an adequate barrier at Canapitsit Beach are essential for maintenance of the entrance channel at its present location, to prevent excessive shoaling of the channel and to protect the outer harbor from southerly exposure.

g. Access to Canapitsit Island is by way of the barrier beach. The Coast Guard station formerly located on Canapitsit Island was abandoned in 1947 and a new station established on the mainland of Cuttyhunk Island. Therefore, the value of such access at this time is limited.

h. The existing car floats have deteriorated badly along the easterly section of Canapitsit Beach, but are relatively intact at the westerly section. The undamaged car floats may be expected to continue to protect the project partially for a number of additional years.

i. A stone structure can be constructed with less difficulty on the beach and the quality of construction would be superior to that of an offshore breakwater with respect to foundation, sandtightness, density and stone interlocking.

j. Future maintenance of a structure located on land is easier.

k. Although parallel twin dikes or breakwaters each dissipate a portion of the wave energy, thus requiring lower structures and smaller armor stone than single structures, in this case there appears to be no advantage since both the dimensions of the proposed structure and the sizes of the required stone are reasonably small.

l. Relocation of the entrance channel may necessitate rock or boulder removal.

m. The approach to any relocated channel would be generally more exposed. Since Cuttyhunk is used for refuge from storms a safe entrance at times of storm is essential.

n. Relocation of the channel may alter the present balance of tidal currents in the area.

o. Relocation of the entrance channel under some plans would render Copicut Neck inaccessible by land.

p. Copicut Neck Beach protects the inner harbor from the northwest. Deterioration and breaching of this barrier would result in exposure of the harbor to the prevailing northwest winds, and may damage shellfish beds at the westerly end of the inner harbor and cause shoaling of the improved anchorage area and the turning basin.

COST ESTIMATES

28. Quantities have been estimated on the basis of the surveys of 1962 shown on Plates 2 and 3 and on the structure dimensions shown on Plate 1 and tabulated in paragraph 21. These quantities are expected to be required if construction is undertaken prior to any breaching of either Canapitsit or Copicut Neck Beaches. Higher quantities will be required if work is delayed until after a breach. The quantities contained in this estimate differ from those in the Appendix as they are based on a modified design which calls for minimal initial construction and compensatory increase in the allowance for future maintenance.

29. Quantities used in the cost estimates are based on lean dimensions, and on in-place weight of 1.65 tons per cubic yard for

placed cover stone and 1.5 tons per c.y. for apron and all other stone. The additional stone required for one foot tolerance above the design lines of the structures has also been computed, but not included in the quantities of the cost estimate. The proposed work has been divided into two phases. Phase 1 includes Section 1, the south half of the Copicut Neck dike, and Sections 6, 7, 8 and 9, which make up the eastern half of the Canapitsit dike. Phase 2 includes Sections 2, 3, 4 and 5, which consist of the north half of the Copicut Neck dike, the west half of the Canapitsit dike, and the south jetty. Phase 2 would be undertaken at a future fiscal year if the necessity therefor became apparent. Following is a tabulation of estimated quantities of stone in tons and excavation in cubic yards. Shown separately are heavy armor stone, AA; other armor stone, A; underlayer stone, B; core stone, C; crushed stone, D; their total used in the cost estimate; additional stone for 1' tolerance, T; and excavation, E.

Section	AA	A	B	C	D	Total	T	E
Phase 1								
1	-	2050	100	100	-	2250	950	300
6	1050	900	150	450	300	2850	700	1300
7	3850	2700	500	1500	900	9450	1850	3300
8	-	2300	200	550	400	3450	1000	1000
9	-	350	-	50	50	450	150	300
Totals Phase 1						18,450	4,650	6,200
Phase 2								
2	-	3150	-	-	-	3150	1200	1000
3	-	2450	-	200	250	2900	1150	1600
4	-	1850	200	450	200	2700	800	1000
5	-	2000	400	-	-	2400	900	100
Totals Phase 2						11,150	4,050	3,700
Grand Total						29,600 tons	8,700 tons	9,900 cy

30. The estimates of cost for accomplishment of the proposed maintenance construction are based on unit prices estimated to be prevailing in July 1963 for quantities within lean dimensions. Following are the estimates of first cost for each phase of construction.

	Phase 1	Phase 2	Total
First Cost of Construction			
Stone, @ $14/ton	$259,000	$156,000	$415,000
Excavation, @ $1.50/c.y.	9,000	6,000	15,000
Contingencies, @ 12%	32,000	19,000	51,000
Engineering and Design	13,000	12,000	25,000
Supervision and Administration	27,000	17,000	44,000
	$340,000	$210,000	$550,000

31. Annual charges are based on a project life of 50 years with an interest rate of 3% per annum. Estimates of maintenance represent the average annual requirements during that period, although in the initial period after construction, and as long as the remaining car floats on Canapitsit Beach continue to serve the project, maintenance requirements are expected to be smaller. Estimates of maintenance include, in addition to the presently proposed construction, the Federal channel, anchorage and the north jetty, on which no work is needed now. Annual charges are estimated to be as follows:

Annual Charges:

Interest		$ 16,500
Amortization		4,900
Maintenance:	Channel and Anchorage	4,000
	Dikes and Jetties	10,000
Total Annual Charges		$ 35,400

SCHEDULE FOR DESIGN AND CONSTRUCTION

32. The proposed project maintenance plan has been divided into two construction phases. Phase 1 includes Section 1 on Copicut Beach and Sections 6, 7, 8 and 9 along the easterly half of Canapitsit Beach. Phase 2 includes Section 2 on Copicut Beach, Sections 3 and 4 along the westerly half of Canapitsit Beach, and Section 5 of the south jetty. It is recommended that the construction of Phase 1 be accomplished as soon as possible and has been scheduled for FY 1965. Delay in the accomplishment of this work is expected to result in cost increases, especially in the event that the barrier beaches are breached. Phase 2 would be scheduled for a future fiscal year if the need became apparent.

33. Field investigations consisting of recent soundings, profiles and land cross-sections are available. Design studies have been completed in preparation of this memorandum. Preconstruction surveys, preparation of standard plans and specifications, invitation for bids and award of a contract for each individual phase of construction could be accomplished within about 2 months after funds are made available. Construction would require about 3-1/2 months for Phase 1, and 2-1/2 months for Phase 2.

34. The fund requirements for preconstruction planning and for the construction contract and overhead for accomplishment of Phase 1 are as follows:

	Fund Requirement		
	Preconstruction Planning	Construction Contract & Overhead	Total Funds Required
FY 1965	$10,000	$330,000	$340,000

OPERATION AND MAINTENANCE

35. The past Federal and local expenditures for project maintenance are described in paragraph 3 of this memorandum. The requirements for future maintenance of the proposed project maintenance plan will include condition studies, dredging of the channel and anchorage, and repairs to the jetties at the entrance and the stone dikes at Canapitsit and Copicut Neck Beaches. Material from maintenance dredging should generally be disposed of on the southwesterly end of Canapitsit Beach in order to provide some nourishment to the beach fronting the proposed structures. The estimated average annual cost of maintenance is $14,000.

BENEFITS

36. The principal benefits derived from the existence and maintenance of the navigation project at Cuttyhunk Harbor are based on its value and use as a refuge. Cuttyhunk Harbor is favorably situated in relation to traffic passing through the Cape Cod Canal. It is used extensively for refuge by pleasure craft during the summer months and by fishing vessels and other craft throughout the year. It is also being used for night stop-over by small boats sailing from Long Island Sound to the Cape Cod Canal.

It is the only harbor available for refuge on the south side of Buzzards Bay and is reported to be preferred to other harbors on the north side.

37. It is reported that, at present, many boatmen consider Cuttyhunk Harbor safer at times of hurricane than New Bedford Harbor, and about 20 yachts were moved from New Bedford to Cuttyhunk Harbor for refuge during a recent hurricane. Upon completion, the hurricane barrier across New Bedford Harbor will make a sheltered harbor where some craft now using Cuttyhunk Harbor may seek refuge. However, at times of approaching hurricanes, and during hurricanes, the tide gates at the navigation opening of the barrier would be closed, probably beginning with a low tide cycle, and a number of craft may be left outside. The nearest harbor where these craft could seek refuge would be at Cuttyhunk.

38. Evidence of the value of the harbor for refuge and as a base for rescue activities are the U.S. Coast Guard installations on the island. It has been estimated that the original installation cost was about $150,000 and upwards of $100,000 was spent for relocation in 1947 from Canapitsit Island to the mainland of Cuttyhunk Island. An adequately maintained harbor is essential for their operations. Rescue missions by the Coast Guard in the area have been 5-10 per month in the summer and about 2 per month during the winter. Since the harbor is presently usable, it is not known whether any vessels would be lost or damaged in the area if Cuttyhunk Harbor was not available. However, it is estimated that about 100 craft, mostly recreational, sought refuge in Cuttyhunk Harbor during the summer of 1962, and fishing vessels, tugs and barges averaged 4-5 per week during the off-season period, with 1-20 craft laying over to wait out a storm simultaneously. It is anticipated that if Cuttyhunk Harbor is not maintained and is allowed to deteriorate, vessel losses and damages would rise, calls for assistance would increase, and the cost of providing equivalent Coast Guard assistance from other harbors would be considerable.

39. An additional indication of the importance of this harbor is the interest of the Commonwealth of Massachusetts, dating back to the beginning of the 20th Century. In the period 1906-1935, prior to authorization of the Federal project, the Commonwealth provided the first improvements to Cuttyhunk Harbor by constructing stone and concrete jetties on both sides of the entrance, and by dredging and maintaining an entrance channel and a turning basin in the inner harbor. These improvements were accomplished at a cost of $94,236, of which $10,300 was contributed by the town of Gosnold. The town also constructed and maintained two pile and timber wharves at a cost of $11,567.

40. Subsequent to authorization of the Federal project, local interest was evidenced again as they shared in the project by cash contribution of $11,643 for 30% of the cost of new work in 1939. Later, as stated in the Preliminary Report of 14 July 1947, local officials indicated willingness for town contribution of 50% of the cost of an additional anchorage area and for furnishing any necessary spoil areas. When restoration of the Canapitsit Beach barrier was undertaken by the Government, the Commonwealth of Massachusetts made a cash contribution of $50,000 in 1950, and in 1954-1955 performed dredging of about 40,000 cubic yards for placement on the barrier at an estimated cost of $51,820, in lieu of a cash contribution.

41. Continued maintenance of the harbor is vital to the inhabitants of the island and of value to summer residents and visitors. Present harbor facilities provide nearly 1000 feet of docking space and can accommodate vessels up to 10-foot draft and 100 feet in length. In addition to the Coast Guard boathouse and dock, there are two town-owned public wharves; one just inside the inner harbor entrance called Town or Mailboat Dock; and the other at the end of the turning basin called Fishermen's or Commonwealth of Massachusetts Pier. In addition, there are the small dock with floating platform of the Cuttyhunk Yacht Club and two or three other privately owned piers, as shown on Plate 1. Water and fuel are available at the public docks throughout the year. There are no boatyards or major repair facilities at Cuttyhunk, as most of the local fishermen accomplish their own repair work or have such work done at New Bedford. Furthermore, since pleasure craft use Cuttyhunk Harbor primarily on transit or for refuge, no demand exists for repair facilities. However, the town has a marine railway adjacent to Fishermen's Pier for use by local residents and for emergency haul outs.

42. Expenditures for maintenance of the harbor facilities by the Commonwealth of Massachusetts include about $34,700 for hurricane repairs to the Town Dock in 1955, $51,793 for reconstruction and extension of Fishermen's Pier in 1959. The Commonwealth is presently (1963) constructing a finger pier marina estimated to cost $36,453. The new marina will consist of a 264' main pier and two 180' finger piers located east of Fishermen's Pier in the inner harbor, as shown on Plate 1. Additional expenditures for maintenance of the Coast Guard facilities, the public harbor facilities, and for construction and maintenance of private facilities have been made by their respective owners, but no estimate is available.

43. Commerce in Cuttyhunk Harbor is limited to building materials, bulk supplies, machinery, general merchandise and other necessities of life for the population of the island, and for servicing local and visiting craft. Practically all fish caught by the local fishing fleet is transported to New Bedford. Fuel landings amount to about 50,000 gallons of gasoline and 60,000 gallons of diesel oil, annually.

44. Commercial vessel traffic in the harbor includes 11 trips annually by barge and tug for fuel transport. The mail boat makes scheduled daily trips from June to September and twice weekly the remainder of the year bringing passengers, freight and supplies from New Bedford. The mail boat and other freight vessels make about 25 additional trips bringing in building materials, bulk supplies, machinery, etc. In addition, the harbor is frequently visited by large Coast Guard Bouy Tenders and other boats with supplies for the local Coast Guard station, and U. S. Navy craft with personnel and supplies for their LORAC station at the westerly end of the island.

45. Most of the fishing and pleasure boat traffic takes place during the summer months from June to September. Reports prior to extension of Fishermen's Pier in 1959 indicated that about 20 boat owners used the facilities regularly, and although about 50 average-size boats could be accomodated confortably, about 100 boats were docked by crowding during the swordfish tournament. The subsequent extension of Fishermen's Pier and the presently constructed marina would provide dock accommodations for a much greater number of boats.

46. Records of overnight tie-ups of pleasure craft in 1962 show 139 in June, 446 in July, 350 in August, 182 in September and 39 in October, or a total of 1156 boat tie-ups from June to October 1962. It is also reported that about 500 customers were sold supplies in the month of July 1962, alone. In addition to boats docked at the available harbor facilities, a number of boats stay in the 10-foot anchorage. During the summer season about 50-60 boats daily on weekdays and up to 100 boats daily on weekends use the harbor for a stop-over, as it is conveniently situated on the route from Long Island Sound to the Cape Cod Canal. It is also reported that on occasion the inner harbor is filled to capacity and a number of boats stay at anchor in the outer harbor.

47. The locally based fishing fleet includes 3 lobster boats 36' long valued at $4,000 each, and 16 fishing charter boats 28'

long valued at $6,000 each. In addition, 5 trawlers 48' long and 6 lobster boats 26' long have used the harbor as a transient port daily and on weekends during the summer of 1962.

48. The permanent locally based recreational fleet consists of 50 rowboats and 66 larger boats with a total value between $200,000 and $500,000. It is composed of the following craft, as reported by the town:

50	Rowboats,	8'-12'	long, each valued at	$500
25	Outboards,	10'-20'	" , "	$500-$2,500
20	Cruisers,	15'-30'	" , "	$5,000-$10,000
4	" ,	31'-50'	" , "	$5,000-$30,000
2	Aux. Sails,	41'-60'	" , "	$30,000-$50,000
12	Sailboats,	10'-20'	" , "	$1,000
3	" ,	21'-30'	" , "	$2,000

49. The town has also estimated and reported the following numbers and composition of the transient recreational fleet:

54	10'-20'	Outboards,	1	day in port, valued at	$1,500
500	10'-20'	Inboards,	1-2	" , "	$5,000
500	15'-30'	Cruisers,	1-2	" , "	$5,000
300	31'-50'	" ,	1-2	" , "	$20,000-$50,000
300	51'-60'	" ,	1-7	" , "	$50,000-$100,000
200	15'-30'	Aux.Sails,	1-2	" , "	$5,000
100	31'-40'	" ,	1-2	" , "	$10,000
100	41'-60'	" ,	1-2	" , "	$20,000-$50,000

On the basis of the above, the total number of 2,054 transient craft may be computed to be equivalent to 317 local boats for a season of 120 days. This fleet has a total value between $700,000 and $1,300,000.

50. The reduction of vessel damage and loss of life derived from continued maintenance of Cuttyhunk Harbor and the additional benefits to the United States from use of the harbor as a base for the U.S. Coast Guard activities and rescue operations, and to the local and transient fishing, charter and pleasure fleets using the harbor, as well as other intangible benefits, are not susceptible to monetary evaluation. It is estimated, however, that these benefits are much larger than the annual cost of $35,400 required for continued maintenance of the harbor. On this basis, it is concluded that undertaking of the proposed project maintenance plan at an early date is feasible and justifiable.

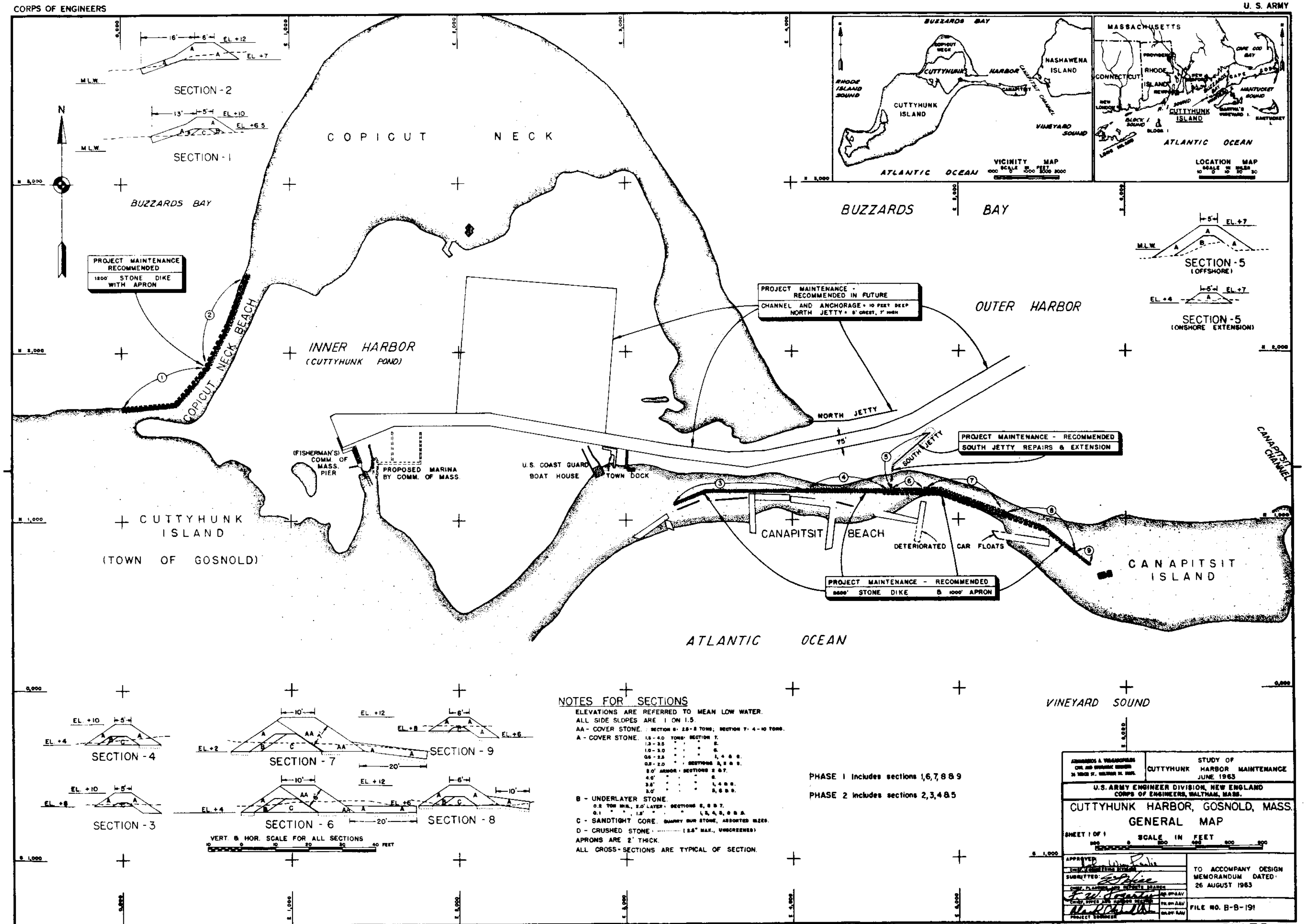
RECOMMENDATION

51. It is recommended that the proposed project maintenance Plan I, which provides for construction of stone dikes on Canapitsit and Copicut Neck Beaches in order to preserve these protective barriers, and reconstruction and extension of the south jetty, as well as future maintenance of the existing channel and anchorage and of the north jetty, as described herein and shown on Plate 1, be approved for maintenance of the Federal navigation project at Cuttyhunk Harbor, Gosnold, Massachusetts.

52. It is also recommended that Phase 1, which includes construction of the eastern half of the Canapitsit dike and the southern half of the Copicut dike, be approved for early maintenance and undertaken in Fiscal Year 1965.

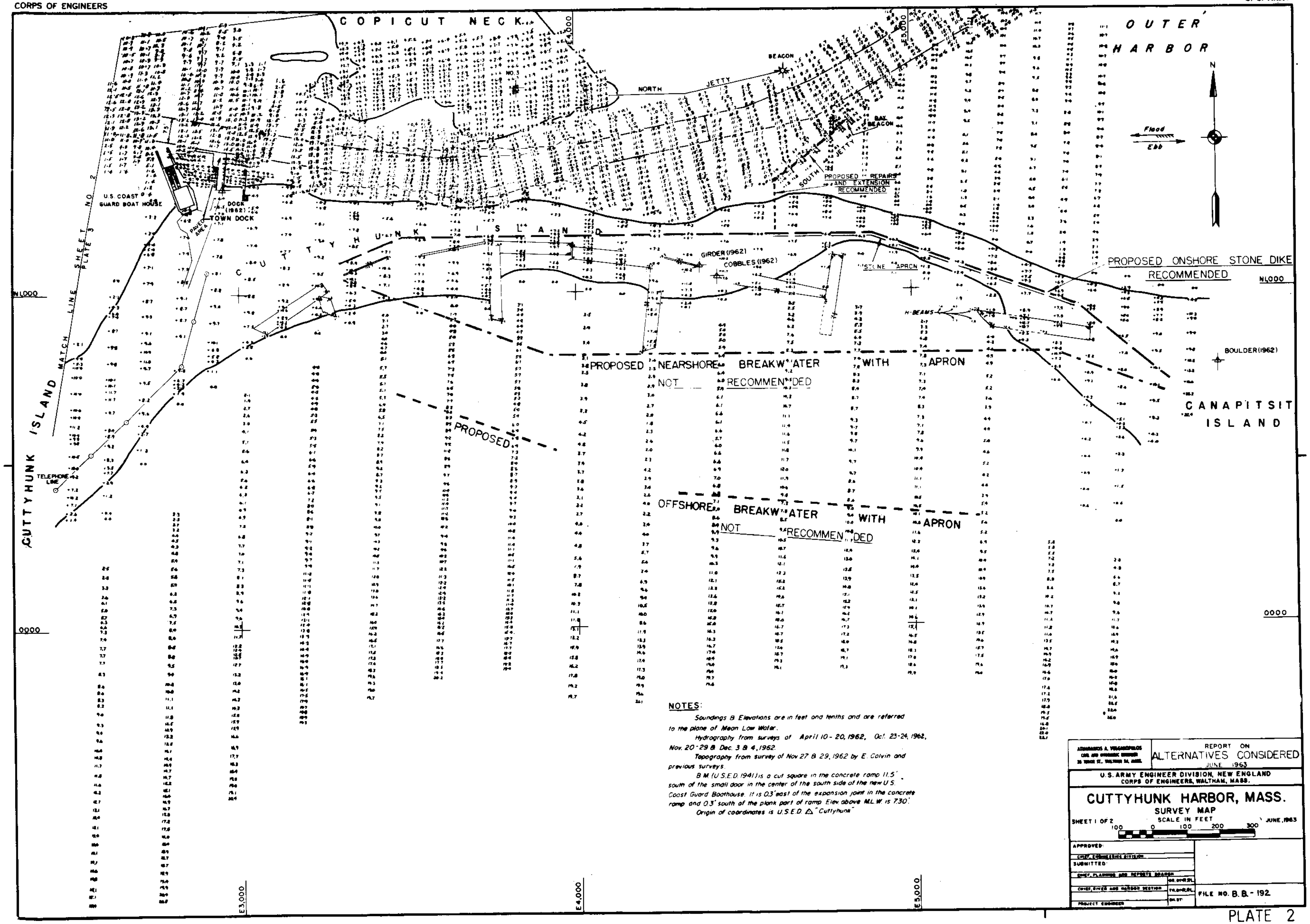
53. The proposed project maintenance construction program is recommended subject to the conditions that local interests provide without cost to the United States all lands, easements, rights-of-way and suitable spoil disposal areas for the construction and maintenance of the project when and as required, and they should also hold and save the United States free from damages that may result from the construction works and maintenance of the project.

Incls. 9
Maps Plates 1-IX
Appendix A


BUZZARDS BAY
COPICUT NECK
INNER HARBOR
(CUTTYHUNK POND)
COPICUT NECK BEACH
PROJECT MAINTENANCE RECOMMENDED
1200' STONE DIKE WITH APRON
PROJECT MAINTENANCE - RECOMMENDED IN FUTURE
CHANNEL AND ANCHORAGE
NORTH JETTY
OUTER HARBOR
NORTH JETTY
75'
PROJECT MAINTENANCE - RECOMMENDED
SOUTH JETTY REPAIRS & EXTENSION
SOUTH JETTY
CANAPITSIT CHANNEL
(FISHERMAN'S) COMM. OF MASS. PIER
PROPOSED MARINA BY COMM. OF MASS.
U.S. COAST GUARD BOAT HOUSE
TOWN DOCK
CANAPITSIT BEACH
DETERIORATED CAR FLOATS
PROJECT MAINTENANCE - RECOMMENDED
STONE DIKE & APRON
CANAPITSIT ISLAND
CUTTYHUNK ISLAND
(TOWN OF GOSNOLD)
ATLANTIC OCEAN
VINEYARD SOUND
VICINITY MAP
NASHAWENA ISLAND
CUTTYHUNK ISLAND
VINEYARD SOUND
LOCATION MAP
MASSACHUSETTS
CONNECTICUT
RHODE ISLAND
ATLANTIC OCEAN
SECTION - 1
SECTION - 2
SECTION - 3
SECTION - 4
SECTION - 5 (OFFSHORE)
SECTION - 5 (ONSHORE EXTENSION)
SECTION - 6
SECTION - 7
SECTION - 8
SECTION - 9
VERT. & HOR. SCALE FOR ALL SECTIONS
NOTES FOR SECTIONS
ELEVATIONS ARE REFERRED TO MEAN LOW WATER.
ALL SIDE SLOPES ARE 1 ON 1.5.
AA - COVER STONE.
A - COVER STONE.
B - UNDERLAYER STONE.
C - SANDTIGHT CORE.
D - CRUSHED STONE
APRONS ARE 2' THICK.
ALL CROSS-SECTIONS ARE TYPICAL OF SECTION.
PHASE 1 includes sections 1,6,7,8 & 9
PHASE 2 includes sections 2,3,4 & 5
STUDY OF CUTTYHUNK HARBOR MAINTENANCE
JUNE 1963
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.
CUTTYHUNK HARBOR, GOSNOLD, MASS.
GENERAL MAP
SHEET 1 OF 1
SCALE IN FEET
APPROVED:
SUBMITTED:
PROJECT ENGINEER
TO ACCOMPANY DESIGN MEMORANDUM DATED: 26 AUGUST 1963
FILE NO. B-8-191

CORPS OF ENGINEERS

U. S. ARMY



NOTES:

Soundings & Elevations are in feet and tenths and are referred to the plane of Mean Low Water.

Hydrography from surveys of April 10 - 20, 1962, Oct. 23-24, 1962, Nov. 20-29 & Dec. 3 & 4, 1962.

Topography from survey of Nov 27 & 29, 1962 by E. Colvin and previous surveys.

B.M. (U.S.E.D. 1941) is a cut square in the concrete ramp 11.5' south of the small door in the center of the south side of the new U.S. Coast Guard Boathouse. It is 0.3' east of the expansion joint in the concrete ramp and 0.3' south of the plank part of ramp. Elev. above M.L.W. is 7.30'.

Origin of coordinates is U.S.E.D. △ "Cuttyhunk"

REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

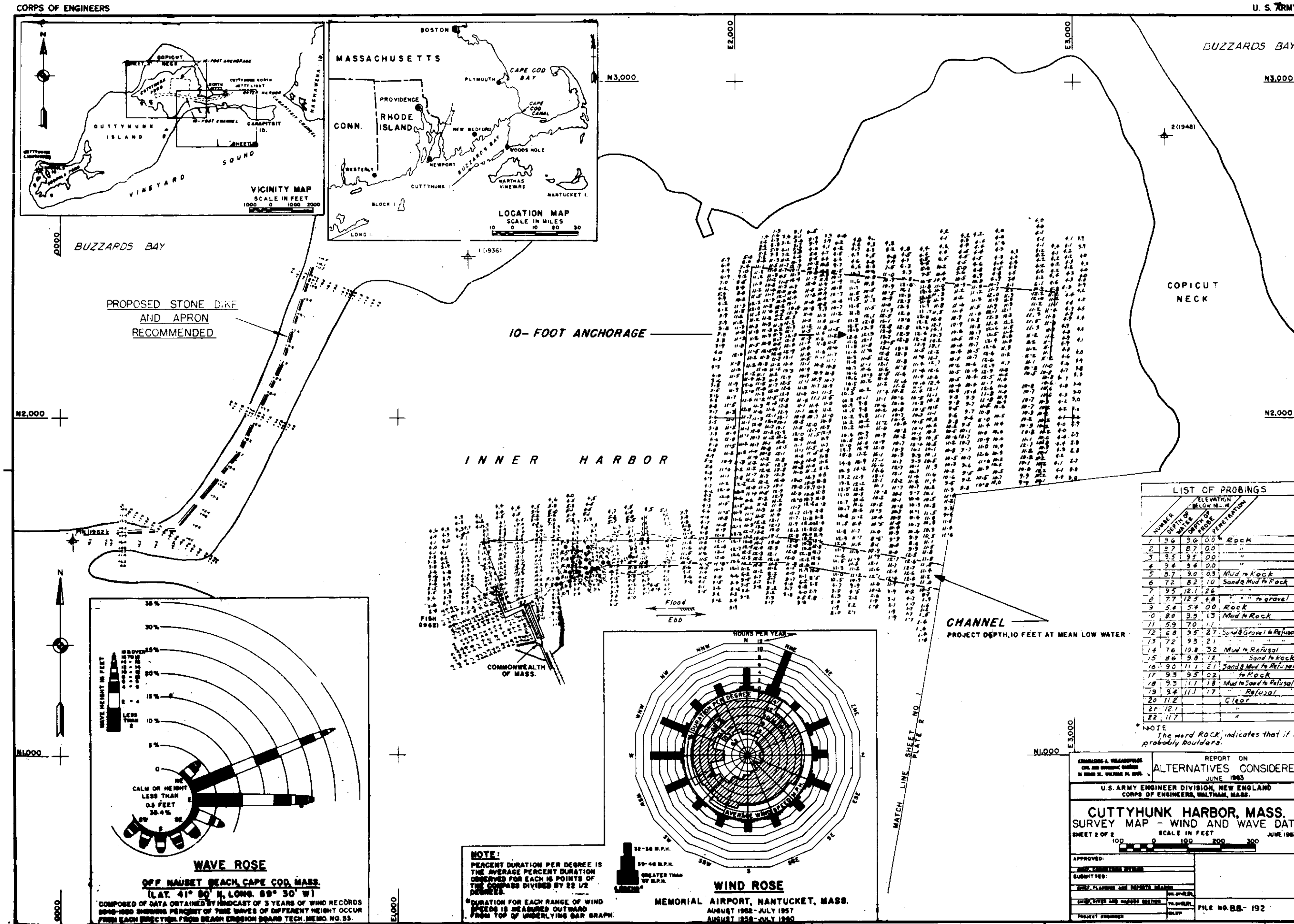
CUTTYHUNK HARBOR, MASS.
SURVEY MAP

SHEET 1 OF 2
SCALE IN FEET
100 0 100 200 300
JUNE, 1963

APPROVED:
CHIEF, ENGINEERING DIVISION
SUBMITTED:
CHIEF, PLANNING AND REPORTS BRANCH
CHIEF, RIVER AND HARBOR SECTION
PROJECT ENGINEER

FILE NO. B.B. - 192

PLATE 2



LIST OF PROBINGS

NUMBER	DEPTH OF WATER (ELEVATION BELOW M.L.W.)	DEPTH OF PROBE (ELEVATION BELOW M.L.W.)	PENETRATION	
1	9.6	9.6	0.0	*Rock
2	9.7	8.7	0.0	"
3	9.5	9.5	0.0	"
4	9.4	9.4	0.0	"
5	8.7	9.0	0.3	Mud to Rock
6	7.2	8.2	1.0	Sand & Mud to Rock
7	9.5	12.1	2.6	" " "
8	7.7	12.5	4.8	" " " to gravel
9	5.4	5.4	0.0	Rock
10	8.0	9.3	1.3	Mud to Rock
11	5.9	7.0	1.1	"
12	6.8	9.5	2.7	Sand & Gravel to Refusal
13	7.2	9.3	2.1	" " "
14	7.6	10.8	3.2	Mud to Refusal
15	8.6	9.8	1.2	" Sand to Rock
16	9.0	11.1	2.1	Sand & Mud to Refusal
17	9.3	9.5	0.2	" to Rock
18	9.3	11.1	1.8	Mud to Sand to Refusal
19	9.4	11.1	1.7	" Refusal
20	11.2			Clear
21	12.1			"
22	11.7			"

* NOTE
The word ROCK, indicates that it is probably boulders.

REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

CUTTYHUNK HARBOR, MASS.
SURVEY MAP - WIND AND WAVE DATA

SHEET 2 OF 2 SCALE IN FEET JUNE 1963

APPROVED:

SUBMITTED:

FILE NO. BB- 192

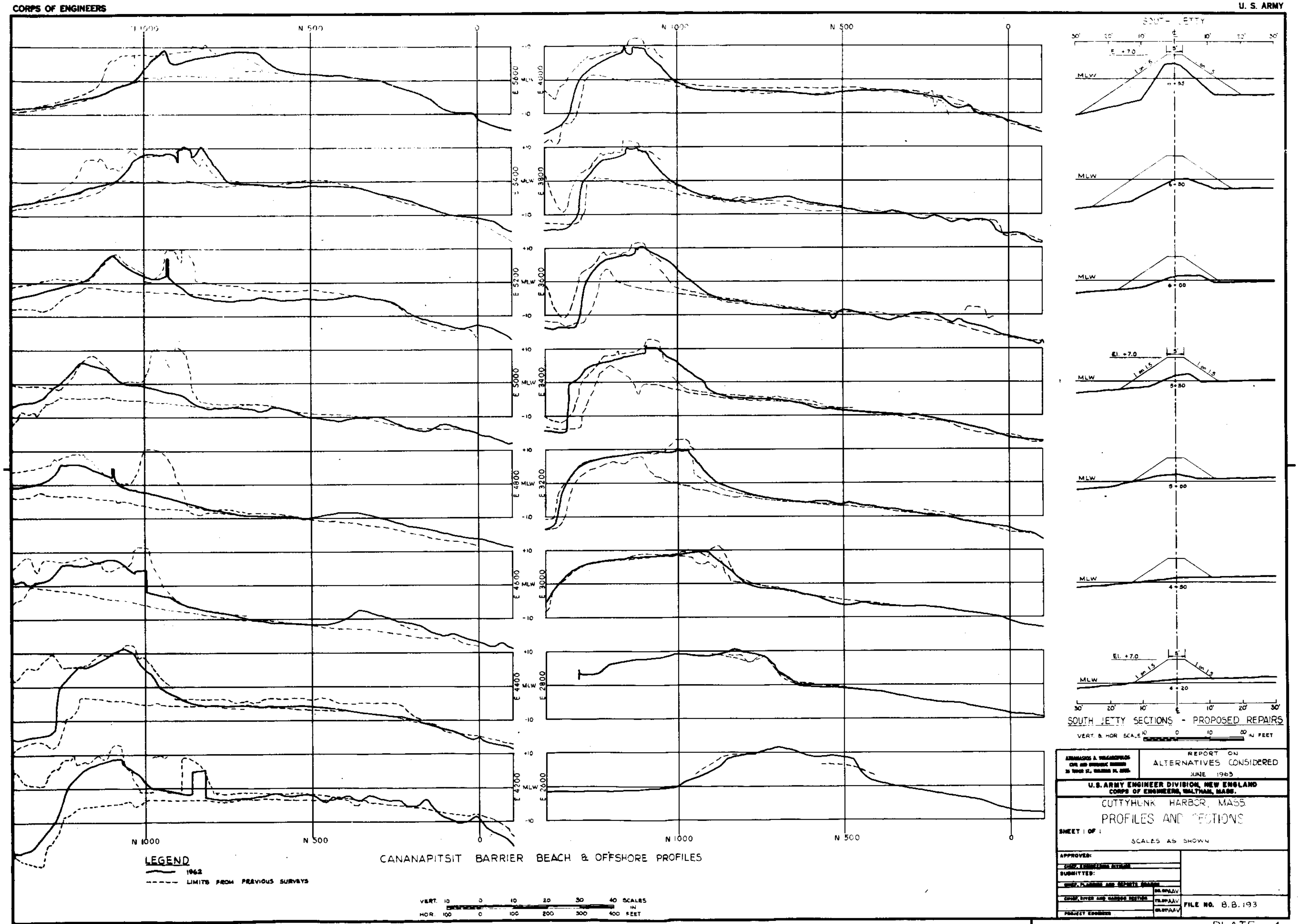

CORPS OF ENGINEERS
U. S. ARMY
N 1000
N 500
0
E 5600
E 5400
E 5200
E 5000
E 4800
E 4600
E 4400
E 4200
E 4000
E 3800
E 3600
E 3400
E 3200
E 3000
E 2800
E 2600
MLW
+10
-10
LEGEND
1962
LIMITS FROM PREVIOUS SURVEYS
CANANAPITSIT BARRIER BEACH & OFFSHORE PROFILES
VERT. 10 0 10 20 30 40 SCALES IN FEET
HOR. 100 0 100 200 300 400
El. +7.0
1 on 1.5
6 + 50
6 + 00
5 + 50
5 + 00
4 + 50
4 + 20
SOUTH JETTY SECTIONS - PROPOSED REPAIRS
VERT. & HOR. SCALE 10 0 10 20 IN FEET
REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.
CUTTYHUNK HARBOR, MASS.
PROFILES AND SECTIONS
SHEET 1 OF 1
SCALES AS SHOWN
APPROVED:
SUBMITTED:
FILE NO. B.B.193

PLATE 4

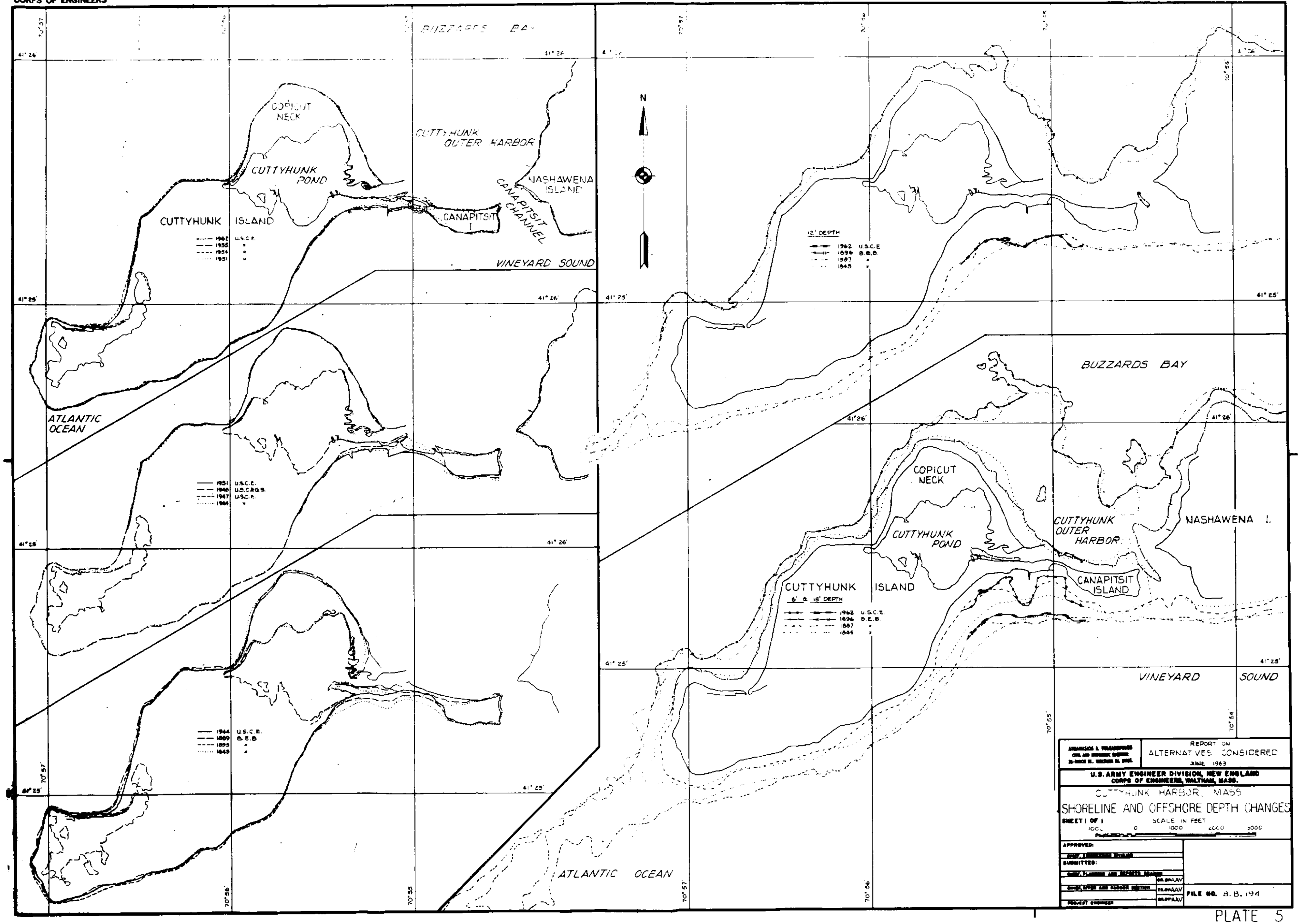
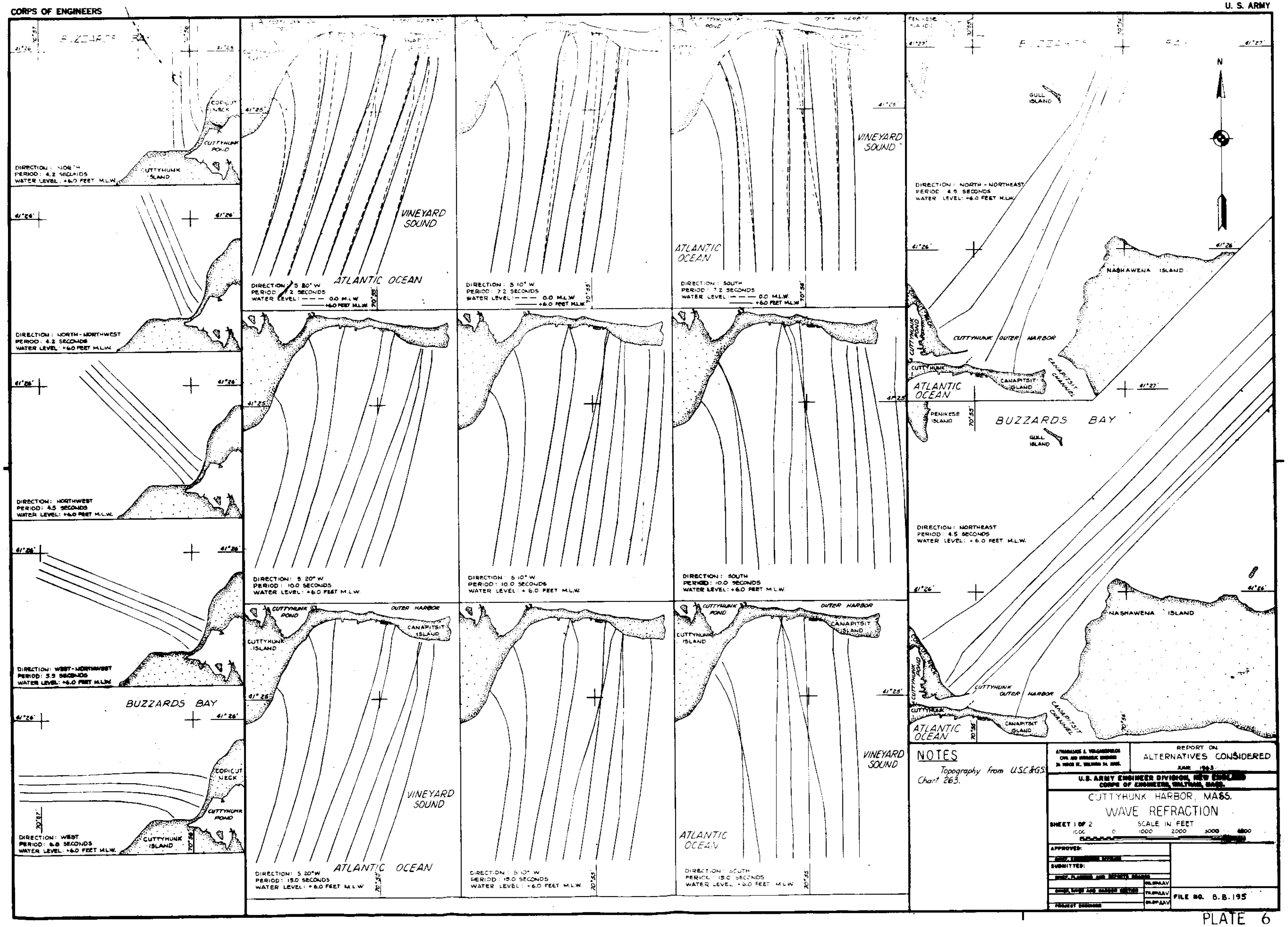
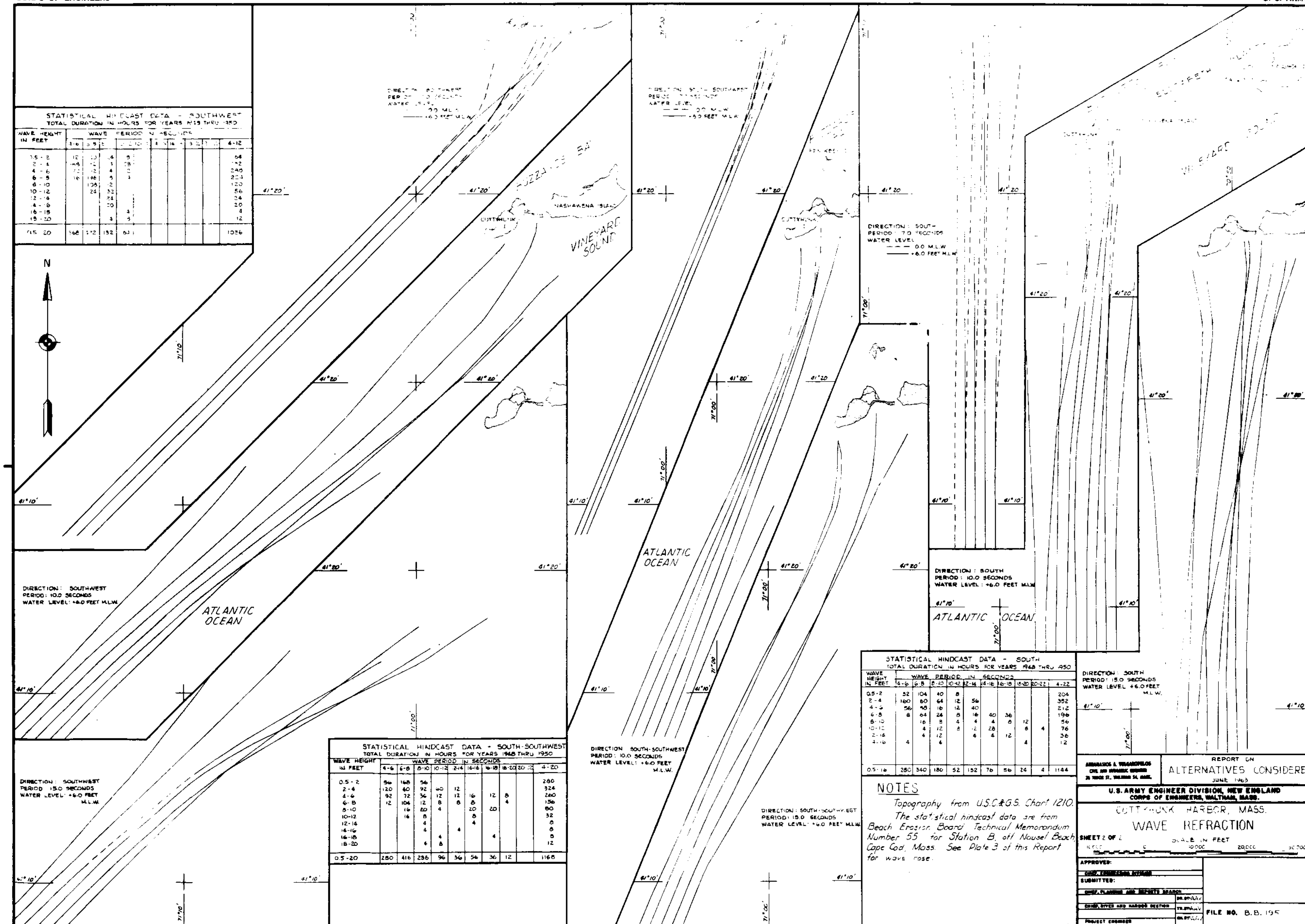

BUZZARDS BAY
COPICUT NECK
CUTTYHUNK POND
CUTTYHUNK OUTER HARBOR
NASHAWENA ISLAND
CANAPITSIT CHANNEL
CANAPITSIT I.
CUTTYHUNK ISLAND
1962 U.S.C.E.
1956 "
1954 "
1951 "
VINEYARD SOUND
ATLANTIC OCEAN
1951 U.S.C.E.
1946 U.S.C.&G.S.
1947 U.S.C.E.
1944 "
1944 U.S.C.E.
1909 B.E.B.
1893 "
1845 "
12' DEPTH
1962 U.S.C.E
1896 B.E.B.
1887 "
1845 "
BUZZARDS BAY
COPICUT NECK
CUTTYHUNK POND
CUTTYHUNK OUTER HARBOR
NASHAWENA I.
CUTTYHUNK ISLAND
CANAPITSIT ISLAND
6' & 18' DEPTH
1962 U.S.C.E.
1896 B.E.B.
1887 "
1845 "
VINEYARD SOUND
ATLANTIC OCEAN
REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.
CUTTYHUNK HARBOR, MASS
SHORELINE AND OFFSHORE DEPTH CHANGES
SHEET 1 OF 1
SCALE IN FEET
1000 0 1000 2000 3000
APPROVED:
SUBMITTED:
FILE NO. B.B.194

PLATE 5



CORPS OF ENGINEERS
U. S. ARMY
BUZZARDS BAY
COPICUT NECK
CUTTYHUNK POND
CUTTYHUNK ISLAND
DIRECTION: NORTH
PERIOD: 4.2 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: NORTH-NORTHWEST
PERIOD: 4.2 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: NORTHWEST
PERIOD: 4.5 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: WEST-NORTHWEST
PERIOD: 5.5 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: WEST
PERIOD: 6.8 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
VINEYARD SOUND
ATLANTIC OCEAN
DIRECTION: S 20° W
PERIOD: 7.2 SECONDS
WATER LEVEL: 0.0 M.L.W. / +6.0 FEET M.L.W.
DIRECTION: S 10° W
PERIOD: 7.2 SECONDS
WATER LEVEL: 0.0 M.L.W. / +6.0 FEET M.L.W.
DIRECTION: SOUTH
PERIOD: 7.2 SECONDS
WATER LEVEL: 0.0 M.L.W. / +6.0 FEET M.L.W.
DIRECTION: S 20° W
PERIOD: 10.0 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: S 10° W
PERIOD: 10.0 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: SOUTH
PERIOD: 10.0 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
OUTER HARBOR
CANAPITSIT ISLAND
DIRECTION: S 20° W
PERIOD: 15.0 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: S 10° W
PERIOD: 15.0 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: SOUTH
PERIOD: 15.0 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
N
GULL ISLAND
PENIKESE ISLAND
NASHAWENA ISLAND
CUTTYHUNK OUTER HARBOR
CANAPITSIT CHANNEL
DIRECTION: NORTH-NORTHEAST
PERIOD: 4.5 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
DIRECTION: NORTHEAST
PERIOD: 4.5 SECONDS
WATER LEVEL: +6.0 FEET M.L.W.
NOTES
Topography from U.S.C.&G.S. Chart 263.
REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.
CUTTYHUNK HARBOR, MASS.
WAVE REFRACTION
SHEET 1 OF 2
SCALE IN FEET
1000 0 1000 2000 3000 4000
APPROVED:
SUBMITTED:
FILE NO. B.B.195

PLATE 6



STATISTICAL HINDCAST DATA - SOUTHWEST
TOTAL DURATION IN HOURS FOR YEARS 1948 THRU 1950

WAVE HEIGHT IN FEET	WAVE PERIOD IN SECONDS									
	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	4-12
0.5 - 2	12	[illegible]	24	8						64
2 - 4	168	12	4	28						[illegible]
4 - 6	72	12	4	2						280
6 - 8	16	196	8	4						224
8 - 10		108	12							120
10 - 12		24	32							56
12 - 14			24							24
14 - 16			20							20
16 - 18				4						4
18 - 20			4	8						12
0.5 - 20	368	572	132	64						1036

STATISTICAL HINDCAST DATA - SOUTH-SOUTHWEST
TOTAL DURATION IN HOURS FOR YEARS 1948 THRU 1950

WAVE HEIGHT IN FEET	WAVE PERIOD IN SECONDS									
	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	4-20
0.5 - 2	56	168	56							280
2 - 4	120	40	92	60	12					324
4 - 6	92	72	36	12	12	16	12	8		260
6 - 8	12	104	12	8	8	8		4		156
8 - 10		16	20	4		20	20			80
10 - 12		16	8			8				32
12 - 14			4			4				8
14 - 16			4		4					8
16 - 18				4			4			8
18 - 20			4	8						12
0.5 - 20	280	416	236	96	36	56	36	12		1168

STATISTICAL HINDCAST DATA - SOUTH
TOTAL DURATION IN HOURS FOR YEARS 1948 THRU 1950

WAVE HEIGHT IN FEET	WAVE PERIOD IN SECONDS									
	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	4-22
0.5 - 2	52	104	40	8						204
2 - 4	160	60	64	12	56					352
4 - 6	56	48	16	12	40					212
6 - 8	8	64	24	8	16	40	36			196
8 - 10		16	8	4	4	4	8	12		56
10 - 12		4	12	8	12	28		8	4	76
12 - 14		4	12		4	4	12			36
14 - 16	4		4					4		12
0.5 - 16	280	340	180	52	132	76	56	24	4	1144

NOTES

Topography from U.S.C.&G.S. Chart 1210.

The statistical hindcast data are from Beach Erosion Board Technical Memorandum Number 55 for Station B, off Nauset Beach, Cape Cod, Mass. See Plate 3 of this Report for wave rose.

ANAGNOSTOS & VOLGAROPULOS
CIVIL AND HYDRAULIC ENGINEERS
WALTHAM 54, MASS.

REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

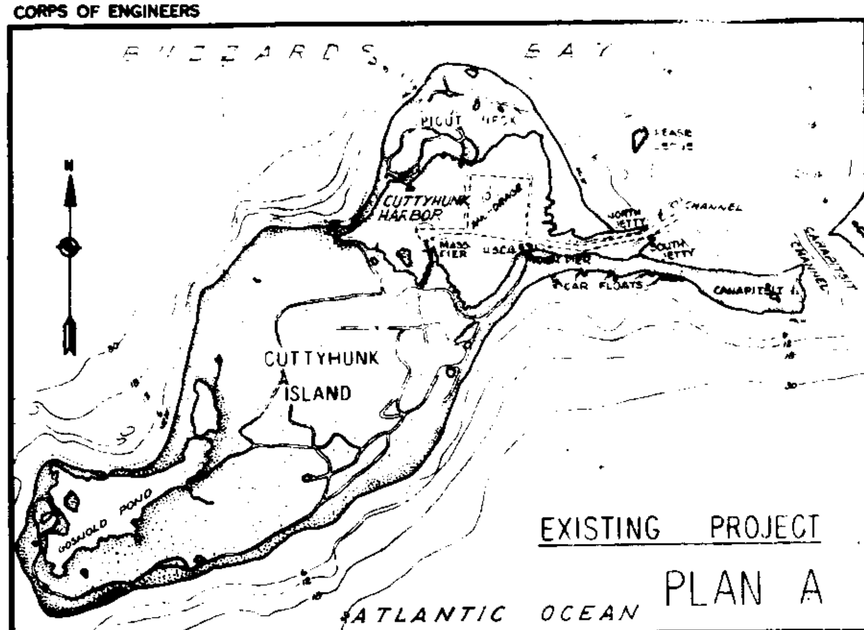
CUTTYHUNK HARBOR, MASS.
WAVE REFRACTION

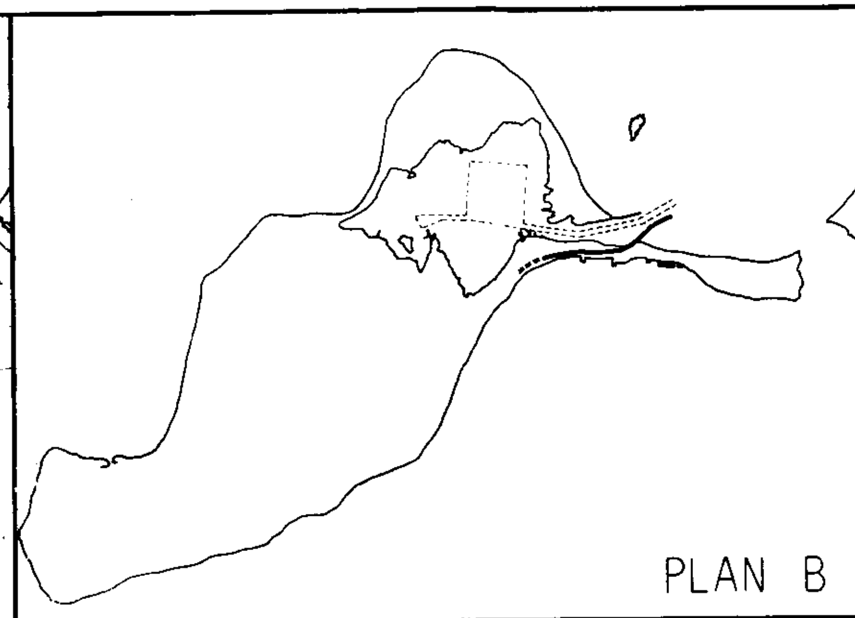
SHEET 2 OF 2

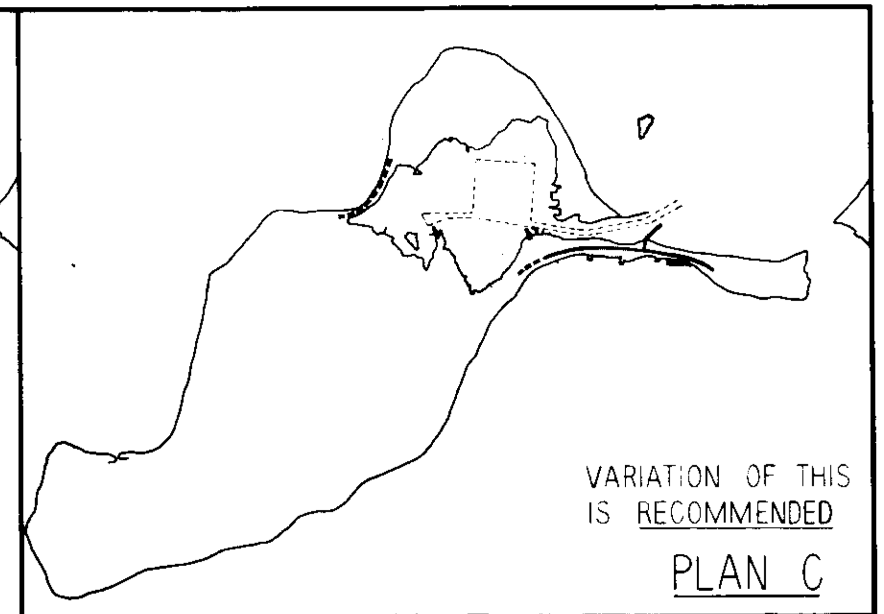
SCALE IN FEET
10,000 0 10,000 20,000 30,000

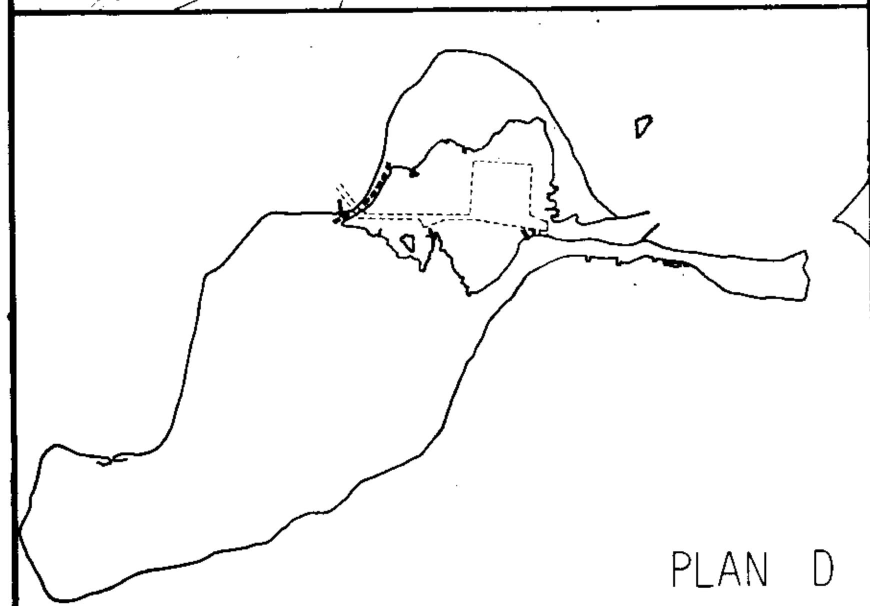
APPROVED:
CHIEF, ENGINEERING DIVISION
SUBMITTED:
CHIEF, PLANNING AND REPORTS BRANCH
CHIEF, RIVER AND HARBOR SECTION
PROJECT ENGINEER
DR. BY AAV
TR. BY AAV
CK. BY AAV

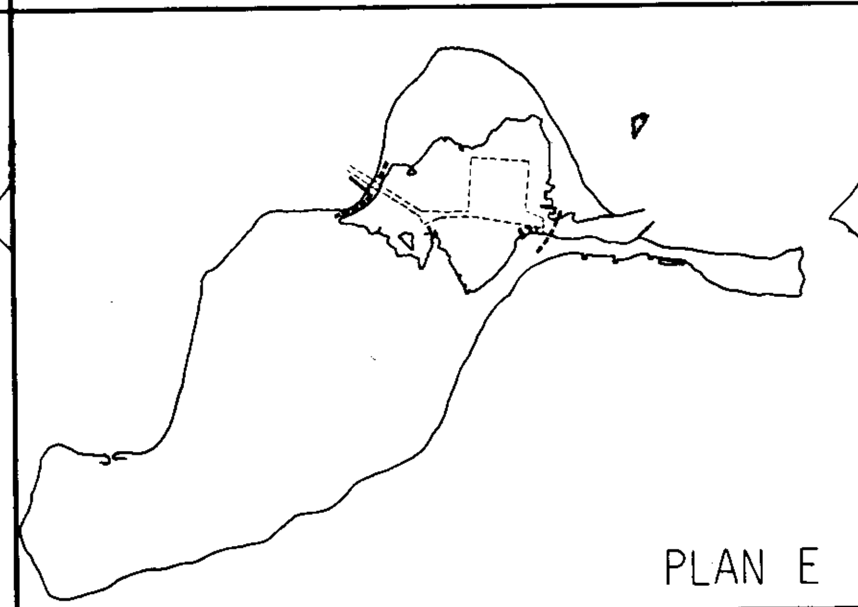
FILE NO. B.B. 195

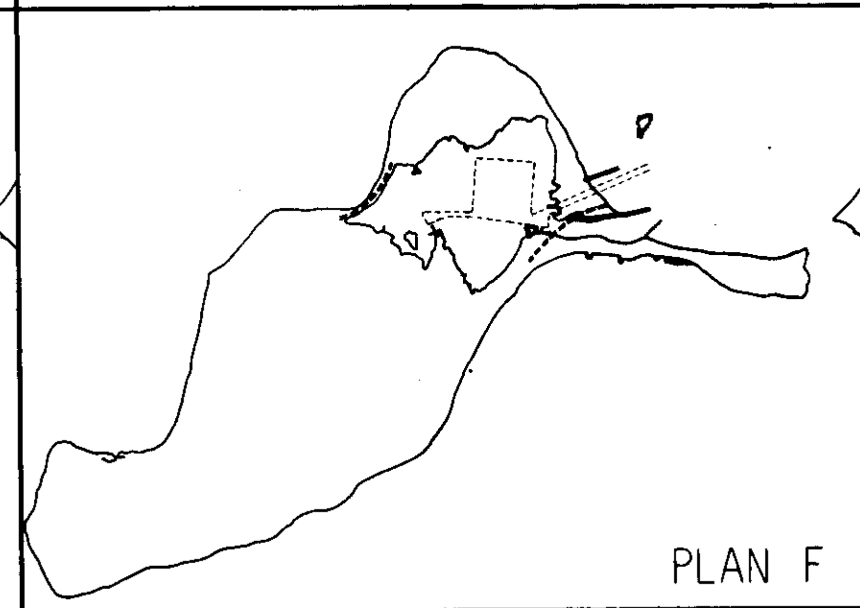


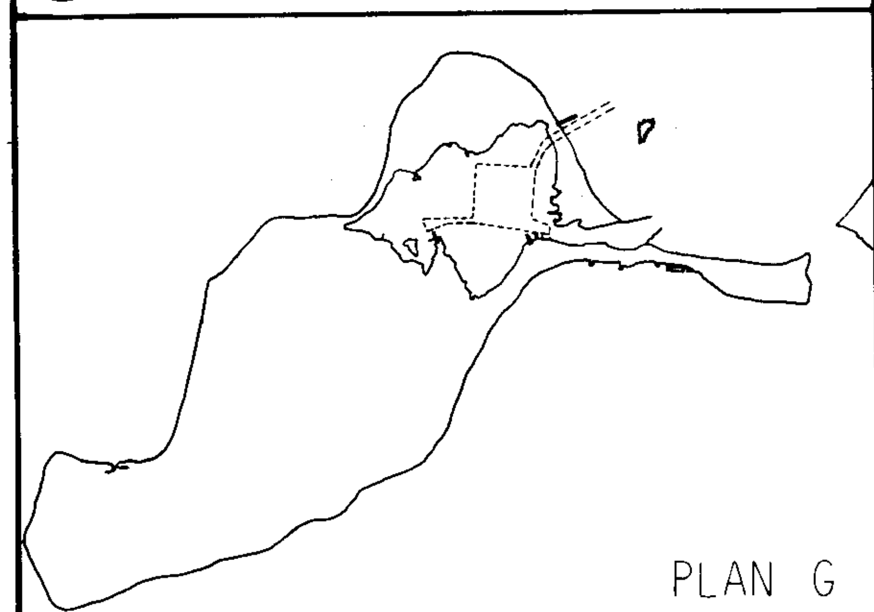


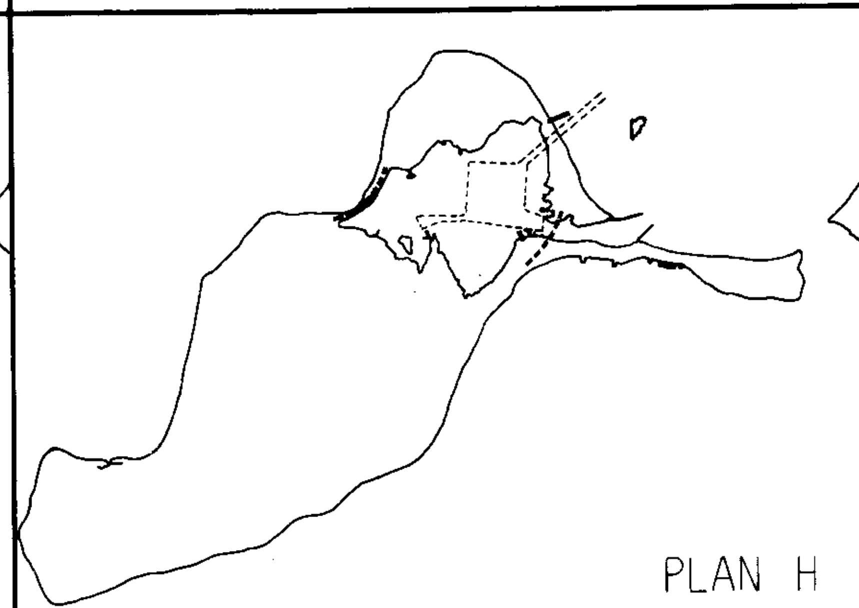












NOTES

All elevations are based on the plane of Mean Low Water.
Topography and offshore contours from U.S.C. & G.S. Chart No. 263.

LEGEND

- Channel or anchorage
- Stone jetty or riprap dike
- Sand dike

REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

CUTTYHUNK HARBOR, MASS.
GENERALIZED ALTERNATIVES

SHEET 1 OF 1

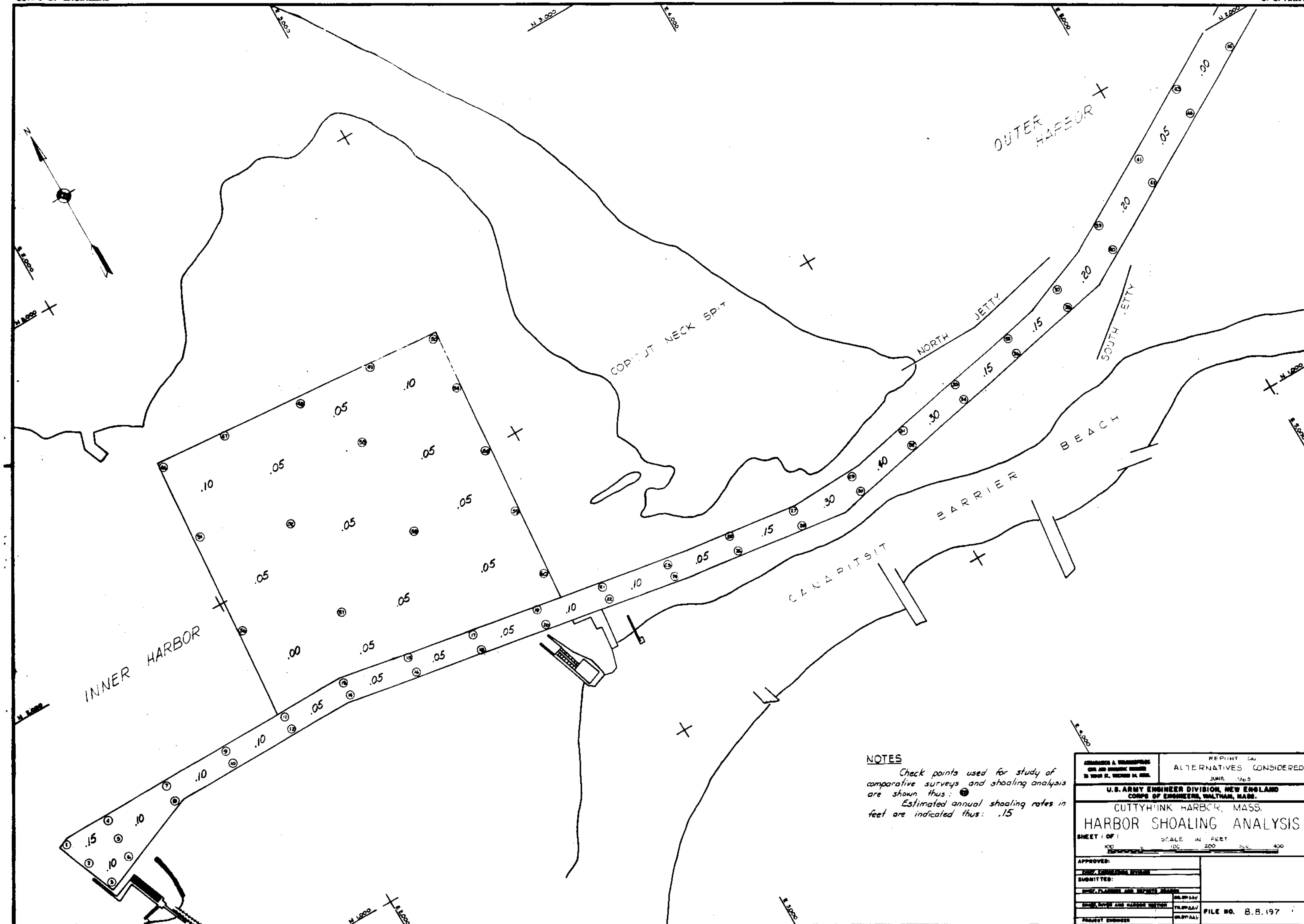
SCALE IN FEET
1000 0 1000 2000 3000

APPROVED:

SUBMITTED:

FILE NO. B.B.196

PLATE 8



NOTES

Check points used for study of comparative surveys and shoaling analysis are shown thus: ⊛

Estimated annual shoaling rates in feet are indicated thus: .15

REPORT ON
ALTERNATIVES CONSIDERED
JUNE 1963

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

CUTTYHUNK HARBOR, MASS.

HARBOR SHOALING ANALYSIS

SHEET 1 OF 1

SCALE IN FEET

100 0 100 200 300 400

APPROVED:

SUBMITTED:

FILE NO. 8.8.197

PLATE 9

DESIGN MEMORANDUM ON
CUTTYHUNK HARBOR, MASSACHUSETTS

APPENDIX - STUDY OF MAINTENANCE,
COMPARISON OF ALTERNATIVES AND PROJECT DESIGN

SUMMARY

1. To determine the most feasible and economic solution to the problem of maintaining a harbor at Cuttyhunk several possible plans were considered and engineering and economic studies were made of certain selected alternatives. This Appendix contains the results of these studies, development of design criteria, and discussion of the effectiveness of several alternative plans. The studies indicate that protection of the Canapitsit Beach barrier is necessary to maintain the entrance channel at its present preferred location. This may be accomplished by construction of substantial riprap structures. Furthermore, to protect the inner harbor from the northwest, a smaller riprap structure is required at Copicut Neck Beach. Plan I is selected as the simplest, most feasible and economical project for Cuttyhunk Harbor.

GENERAL

2. This Appendix includes detailed study of two alternative plans. Both plans provide for maintenance of the Cuttyhunk Harbor channel at its present location and for strengthening the barrier beaches to the south of the present channel and to the west of the inner harbor. The two selected plans are variations of Plan C, shown on Plate 8. The principal difference between these plans lies in the method of protecting the barrier beach to the south of the channel, which connects Cuttyhunk and Canapitsit Islands. One plan calls for a single massive rock structure, the other for a pair of parallel smaller rock structures. Alternative locations of these structures were also considered as further variations of the selected plans. These plans have been studied in detail, their effectiveness analyzed and their relative advantages and disadvantages evaluated in order to determine the most feasible and economic solution.

3. The selected alternatives and their variations are described below:

Plan I. High rock dike with stone apron located on top of the Canapitsit barrier beach. Repairs and landward extension of the south jetty. Stone mound and apron at the Copicut Neck Beach.

Plan II. High rock dike with stone apron located near the southerly shore of the Canapitsit barrier beach. Repairs and landward extension of the south jetty. Stone mound and apron at the Copicut Neck Beach.

Plan III. Low rock dike located on top of the Canapitsit barrier beach. Low riprap breakwater with stone apron located near the southerly shore of the Canapitsit barrier beach. Repairs and landward extension of the south jetty. Stone mound and apron at the Copicut Neck Beach.

Plan IV. Low rock dike located on top of the Canapitsit barrier beach. Low riprap breakwater with stone apron located offshore to the south of Canapitsit barrier beach, in two sections. Repairs and landward extension of the south jetty. Stone mound and apron at the Copicut Neck Beach.

4. In addition to the above plans, some consideration has been given to other alternative solutions as shown on Plate 8. However, these were not considered to merit further study, and are not discussed in this Appendix.

5. This Appendix also contains the results of various engineering studies made to permit a better understanding of the problems in the project area.

STATEMENT OF THE PROBLEM

6. The principal problem at Cuttyhunk Harbor is related to the preservation of the protective beach barrier located along and to the south of the present entrance channel. This barrier connects Cuttyhunk and Canapitsit Islands and shelters the channel and harbor from a potential southerly ocean exposure. After a history of erosion, breaches and construction of various protective measures, the barrier beach has eroded to a critical degree and is again in danger of breaching.

7. Another important problem at Cuttyhunk Harbor is related to the preservation of the beach barrier which connects Copicut Neck to Cuttyhunk Island and shelters the Inner Harbor from the

northwest. Although there is no record of any previous breaching of this barrier, it has been eroding and shifting harborward, and, at the present time, it is being overtopped by spring tides and is in danger of being breached.

WINDS AND STORMS

8. Study has been made of the wind records at Nantucket, Massachusetts, for the periods August 1952 - July 1957 and August 1958 - July 1960, and of a 9-year summary of winds of over 30 miles per hour, of the wind records at Providence, Rhode Island, for the period October 1949 - September 1961, and of the wind records at Block Island, Rhode Island, for the period 1921 through 1939, and of a 10-year summary of winds above 32 miles per hour during the period 1936 through 1945.

9. A wind rose developed from the compiled records at Nantucket, Mass., is included on Plate 3. The predominating winds at this station are from the SW, WSW and WNW, while storm winds predominate from the NNE, NE and ENE directions.At the Providence, R. I., station winds are predominant from the S, SSW, SW, WNW and NW. At Block Island, R. I., winds also predominated from the southwest to the northwest directions.

10. Storm winds of over 32 miles per hour at the above three stations show annual durations exceeding 5 hours per 22.5° from the N, NNE, ENE, ESE, WSW, W and WNW for Nantucket and from the SSW for Providence, and annual durations exceeding 10 hours per 45° from the north, northeast, west and northwest for Block Island. Obviously, the inland location of Providence, R. I., has influenced the wind intensity. The study area is relatively exposed and, although it is located at the geographic center of the three weather stations, it is considered that the records at Nantucket and at Block Island are more representative of conditions affecting Cuttyhunk. Furthermore, the records at Nantucket being more detailed have been used more extensively in this study.

11. A 9-year* summary of winds over 30 m.p.h., from records at Nantucket, Mass., was analysed and adjusted on the basis of an assumption that 10% of the winds of each adjoining direction are part of the central storm, which had shifted, and do not, therefore, constitute separate storms. The pertinent data from this summary and the adjusted figures are listed below:

Principal Direction	No. Occurrences		Avg. Duration (hours)		Avg. Wind Speed (m.p.h.)	
	Sum.	Adj.	Sum.	Adj.	Sum.	Adj.
N	9	7.2	11	13.7	35	35.0
NNE	13	10.4	14	15.9	35	35.2
NE	9	7.2	14	18.0	37	36.9
ENE	9	7.2	12	14.9	38	38.0
E	5	4.0	12	16.3	36	36.6
ESE	9	7.2	7	8.2	34	34.5
SE	6	4.8	6	7.0	33	33.2
SSE	1	0.8	4	11.0	30	31.8
S	4	3.2	6	6.2	33	32.5
SSW	4	3.2	5	6.6	32	32.6
SW	4	3.2	11	15.0	34	33.8
WSW	11	8.8	9	11.0	33	33.2
W	8	6.4	12	15.1	34	33.5
SNW	10	8.0	7	9.6	33	33.1
NW	12	9.6	7	8.2	34	34.0
NNW	2	1.6	5	16.8	33	34.2

*(Jan. 1945-Dec. 1950; July 1956-June 1957 and July 1958-June 1960)

WAVES

12. Waves from all directions reach Cuttyhunk Island. There are limited avilable wave observations in the area. Waves from the north to the northeast affect the outer harbor, the entrance channel and thespit extending south-southeasterly from Copicut Neck. Waves primarily from the south to the southwest affect the barrier beach which connects Cuttyhunk and Canapitsit Islands. The barrier beach which connects Copicut Neck to Cuttyhunk Island is affected by waves from the northwesterly quadrant.

13. The effective fetch in Buzzards Bay to the Gull Island buoy in Cuttyhunk outer harbor is 8.8, 10.5 and9.4 nautical miles from the N, NNE and NE, respectively. The effective fetch in Buzzards Bay to the north jetty of the entrance channel is 8.0, 7.8 and 7.3 nautical miles from the N, NNE and NE, respectively.

14. The effective fetch forlocally generated waves in the Vineyard Sound - Atlantic Ocean area is dependent on the fetch field (F_f), which is the product of wind speed and duration. On this basis, a series of formulae were developed for the effective fetch, (F_e), applicable to the barrier beach between Cuttyhunk anc Canapitsit Islands. Certain selected formulae are listed below:

<u>South:</u> For F_f over 220 naut. miles; $F_e = 9.14 + 0.727F_f$
For 220 over F_f over 11 n.m.; $F_e = 0.952 + 0.765F_f$

<u>South-southwest:</u> For F_f over 205 n.m.; $F_e = 28.72 + 0.639F_f$
For 205 over F_f over 190 n.m.; $F_e = 18.9 + 0.686F_f$
For 190 over F_f over 171 n.m.; $F_e = 10.25 + 0.731F_f$
For 171 over F_f over 32 n.m.; $F_e = 2.86 + 0.775F_f$

<u>Southwest:</u> For F_f over 200 n.m.; $F_e = 50.6 + 0.419F_f$
For 200 over F_f over 179 n.m.; $F_e = 28.65 + 0.524F_f$
For 179 over F_f over 165 n.m.; $F_e = 19.37 + 0.575F_f$
For 165 over F_f over 62 n.m.; $F_e = 11.0 + 0.626F_f$

15. Ocean waves from the south, south-southwest and the southwest are generated over an unrestricted fetch and are subject to all storms which may occur over this practically unlimited fetch. These waves undergo a process which may include several cycles of regeneration and decay before they reach the study area. Therefore, wave forecasting methods are not readily applicable to these ocean waves and data compiled by hindcasting methods are used, as discussed later.

16. The effective fetch in Rhode Island Sound, applicable to the barrier beach between Copicut Neck and Cuttyhunk Island, is 40.9, 17.9, 7.6, 6.2 and 6.1 nautical miles from the W, WNW, NW, NNW and N, respectively. In addition, there are listed below certain selected formulae for shorter fetch fields:

<u>West:</u> For 217 over F_f over 194 n.m.; $F_e = 32.8 + 0.0372\ F_f$
For 194 over F_f over 174 n.m.; $F_e = 24.9 + 0.0775\ F_f$
For 174 over F_f over 57 n.m.; $F_e = 17.4 + 0.1207\ F_f$

<u>West-northwest:</u> For 126 over F_f over 66 n.m.; $F_e = 12.46 + 0.043F_f$
For 66 over F_f over 31 n.m.; $F_e = 9.8 + 0.0834F_f$

17. Waves approaching the three significant sectors of Cuttyhunk Harbor are generated in either deep or transitional

water. The transitional depths are much nearer to the deep water limit. Therefore, the method for deep water wave forecasting is considered to be adequate for the study area. Computations by this method give the following characteristics:

	Using 9-year wind summary			
	Unadjusted		Adjusted	
Location and Direction	Height H_o(ft)	Period T (sec)	Height H_o(ft)	Period T(sec)
Bell buoy, 1/2 mile east of Gull Island				
N	4.5	4.6	4.5	4.6
NNE	4.8	4.8	4.8	4.8
NE	4.9	4.8	4.9	4.8
Cuttyhunk Harbor entrance, at north jetty				
N	4.3	4.5	4.3	4.5
NNE	4.25	4.5	4.3	4.5
NE	4.4	4.5	4.4	4.5
Canapitsit barrier beach (generated locally)				
S	8.3	7.1	8.3	7.1
SSW	7.3	6.6	8.5	7.2
SW	11.6	8.8	13.3	9.6
Copicut Neck Beach				
W	7.9	6.8	7.8	6.75
WNW	5.55	5.45	5.55	5.45
NW	4.1	4.4	4.1	4.4
NNW	3.8	4.2	3.8	4.2
N	3.8	4.2	3.8	4.2

18. Waves generated in the Buzzards Bay area with relation to the Cuttyhunk Harbor entrance have also been computed by shallow water methods. Water depths and bottom profiles have been analyzed and effective values computed by a similar method as used for the effective fetch computations. The results are:

Method	Wave Height in feet	Wave Period inseconds
Bretschneider's	N 7.7;NNE 8.1;NE 8.3	N 4.5;NNE 4.5;NE 4.5
Thysse & Schijf's	12.3; 12.4; 13.6	4.8; 4.8; 5.1

19. The shallow water wave methods of wave forecasting, shown above, are in reasonable agreement with the deep water wave method in the computed values of the wave periods. However, they indicate excessive wave heights, since the effective depths in the area are in the transitional and near-deep water range, where the shallow water methods are not reliable.

20. Characteristics of ocean waves computed from 3 years of synoptic weather charts (1948-1950) by hindcasting methods are included in the Beach Erosion Board's Technical Memorandum No. 55, entitled "North Atlantic Coast Wave Statistics Hindcast". A station located off Nauset Beach, Cape Cod, Mass., is the nearest to the study area and is considered to have reasonably similar characteristics forwaves from the southerly quadrant. A wave rose for this station is included on Plate 3. Tables of wave heights, periods and durations for the south, south-southwest and southwest directions are included on Plate 7. These statistics briefly show the following ranges of values, which may be modified some if a longer period of hindcast records were used:

	S	SSW	SW
Maximum wave height	14-16 ft	18-20 ft	18-20 ft
Periods for maximum height	4-20sec	8-12sec	8-12sec
Maximum wave period	20-22sec	18-20sec	10-12sec
Heights for maximum period	10-12 ft	4- 8 ft	0.5-20 ft

21. Wave refraction diagrams have been prepared for a series of approaches and conditions relating to the three significant sectors of Cuttyhunk Harbor and to the study area in general. These refraction diagrams are shown on Plates 6 and 7. Plate 6 includes wave refraction in Buzzards Bay, Rhode Island Sound and Vineyard Sound in the vicinity of Cuttyhunk Island. Plate 7 includes wave refraction diagrams inthe Atlantic Ocean to the south of Cuttyhunk Island and supplements the diagrams of Plate 6 in this quadrant.

22. Waves generated in Buzzards Bay are subjected to refraction due to many shoals and the offshore slopes of Penikese, Gull and Nashawena Islands. Waves from the north progressing towards

the Outer Harbor are either intercepted and broken at Penikese and Gull Islands, or are refracted and wave trains are forced to override each other and expand. These northerly waves are, therefore, of little consequence to the Outer Harbor and the entrance channel to Cuttyhunk Harbor. Waves from the north-northeast expand as they traverse through the Outer Harbor and are thus reduced in size, as shown on Plate 6. Waves from the northeast, also shown on Plate 6, indicate contraction of the orthogonals in the vicinity of the north jetty and expansion along Canapitsit Island and Beach and at the upper portion of the Copicut Neck spit.

23. A change in the distance between orthogonal lines of wave trains, shown in refraction diagrams, signifies a change in the wave height which is proportionate to the invert of the square root. Expansion of 4 times means reduction by 1/2 of the wave height. Contraction of the orthogonals by 1/4 means increase of 2 times of the wave height.

24. Waves generated in Rhode Island Sound and lower Buzzards Bay approach Copicut Neck Beach from the northwesterly quadrant. Refraction diagrams for waves from the west, west-northwest, northwest, north-northwest and north are shown on Plate 6. Due to the depths in the offshore area, refraction of all wave approaches is limited. At the Copicut Neck beach waves are, generally, either unaltered or slightly reduced.

25. Waves generated by local storms and ocean waves approaching the study area from the southerly quadrant experience refraction due to offshore shoals which extend southwesterly from Cuttyhunk Island and Martha's Vineyard, as well as to the offshore slopes of these islands. Because this area is subjected to waves of various characteristics, refraction diatrams were prepared for three sets of wave periods; 7, 10 and 15 seconds. A tidal level of 6 feet above M. L. W. was used. In addition, the 7-second period waves were refracted on the basis of a tidal level at Mean Low Water. The overall refraction of waves from the south, south-southwest and southwest is shown on Plate 7. The local refraction of these waves as they approach the Canapitsit barrier beach is shown on Plate 6 with orthogonals from the south and at intervals of 10 degrees to the west.

26. Refraction of waves from the south indicates nearly unaltered waves in the approach area for 7-second waves, some overriding of orthogonals and concentration in the approach to the barrier beach adjacent to Canapitsit Island for 10-second waves,

and considerable over-riding of orthogonals and dispersion with some concentration off Canapitsit Island for 15-second waves. The 7-second waves refracted at the MLW tidal level show some concentration off Canapitsit Island and more dispersion elsewhere than the refraction condition at 6 feet above MLW. More intense refraction is generally expected at the lower tidal level.

27. Refraction in the approach area of waves from the south-southwest indicates a small expansion of the 7-second waves, a concentration off to the south of Cuttyhunk Pond with over-riding orthogonals of 10-second waves, and dispersion of the orthogonals of 15-second waves in the vicinity of Canapitsit barrier beach.

28. Waves in the approach area from the southwest are generally refracted and dispersed, thus resulting in substantial reduction of deep water waves before they reach the study area.

29. Local, near-shore refraction of waves reaching the southerly shore of Canapitsit barrier beach, within one mile from shore, indicates general concentration at the center of the barrier beach and to the east therefrom. Waves reaching the westerly half of the barrier beach are generally reduced in height.

30. The net result due to refraction in the offshore approach area and in the local near-shore area south of the Canapitsit barrier beach is amplification of the waves reaching the easterly half of the barrier beach and reduction in the height of waves reaching the westerly half. It appears that the potential for amplification exceeds the supportable wave sizes at the depths available. Therefore, design waves at structures along the easterly half of the barrier beach should be governed by existing and expected bottom depths fronting such structures. Design waves for the westerly half of the barrier beach would also be limited by the available bottom depths, where this may be the criterion. However, the wave height should be at or smaller than the deep water size.

31. The only wave observations known to have been made in the general area were taken off the south side of Cuttyhunk Island, between July 1946 and May 1947, by personnel of Woods Hole Oceanographic Institution and reported on in a paper published by Massachusetts Institute of Technology and Woods Hole Oceanographic Institute, entitled "Results of Research on Surface Waves of the Western North Atlantic", by H. R. Seiwell. The gaging equipment used was somewhat experimental in nature and the observations

were relatively few in number. Following is a summary of wave height statistics as presented in this report:

	SPRING	SUMMER	AUTUMN
Mean wave height, (feet)	3.5	3.2	4.9
25 per cent cumulative occurrence	0 to 1.5	0 to 1.5	0 to 1.8
50 " " " "	0 to 2.8	0 to 2.5	0 to 2.9
75 " " " "	0 to 4.9	0 to 3.9	0 to 7.3
95 " " " "	0 to 9.0	0 to 9.5	0 to 14.5
Highest wave of each season, (feet)	16	15	22

32. The above observations are not directly comparable to the results of statistics by hindcast methods. However, they appear to bein general agreement.

TIDES AND CURRENTS

33. No tidal or current observations have been made in connection with the present study, nor by any of the previous studies in the study area. The U. S. Coast and Geodetic Survey Tide Tables lists the following mean and spring tidal ranges at and in the vicinity of Cuttyhunk Harbor:

Place	Relative position from Cuttyhunk Pond	Ranges Mean	Ranges Spring
Cuttyhunk Pond entrance	-	3.4	4.2
No Mans Land Island	11 naut. miles SSE	3.0	3.6
Gay Head	6 " " SE	3.0	3.6
Menemsha Bight	8 " " ESE	2.7	3.4
Quicks Hole, south side	4 " " E	2.5	3.1
" " , north "	4 " " ENE	3.5	4.4
Dumpling Rocks	7 " " N	3.7	4.6
Penikese Island	1.5 " " N	3.4	4.2
Westport Harbor	9 " " NNW	3.0	3.7
Sakonnet, R. I.	13 " " W	3.3	4.1
Newport, R. I.	19 " " W	3.5	4.4

34. Analysis of U.S.C.&G.S. records for Newport, Rhode Island, indicates that tides rise above the plane of mean high water by approximately one foot or more 134 times per year, by two feet or more 8 times per year, by 2.5 feet or more once per year, by 3.0 feet once every 2.5 years and 3.5 feet or more once in 7 years, on the basis of 7 years of tidal observations.

35. Another analysis of hurricane or storm tides based on 30 years of record at Newport or New Bedford indicates that the percent chance of occurrence in any one year of tidal rises above the plane ofmean high water are as follows: 100% for 2.4 feet; 80% for 2.7 feet; 60% for 5.3 feet; 40% for 5.8 feet; and 20% for 6.2 feet. All of the above are applicable to New Bedford. Similar figures for Newport would be: 100% for 2.4 feet; 80% for 2.5 feet; 60% for 2.7 feet; 40% for 2.9 feet; and 20% for 3.3 feet.

36. The highest observed tide at Cuttyhunk Harbor was in the order of 13.0 feet and occurred on September 21, 1938; a rise of 9.6 feet above the plane of mean high water.

37. On the basis of the above analyses of tides in the vicinity of the study area, a design tide of 6.0 feet above the plane of Mean Low Water has been selected. This tidal level has a frequency of about one year and is considered adequate for the requirements of the project.

38. Currents in the vicinity of Cuttyhunk Harbor are listed in the U. S. Coast & Geodetic Survey Current Tables. At the Canapitsit Channel the average velocity at the strength of current is 2.2 knots and the spring velocity 2.4 knots. Between Gull and Nashawena Islands the average and spring velocities are 1.0 and 1.2 knots, respectively. At a point 1/4 mile south of Penikese Island the currents are 0.8 and 1.0 knot, and at 3/4 mile northwest of Penikese Island the currents are 1.1 and 1.3 knots. One mile west of Cuttyhunk Island the average and spring tidal currents are listed as 1.0 and 1.2 knots, respectively.

39. There are no listings of currents at the entrance channel of Cuttyhunk Harbor. The Inner Harbor, or Cuttyhunk Pond, has an area of about 90 acres at low water and 110 acres at high water. Assuming a sinusoidal tidal curve the maxima rates of change in the water level are 0.9 ft/hr and 1.1 ft/hr for the mean and spring ranges, respectively. Peak tidal flows may thus be computed to be 1,100 and 1,300 cubic feet per second for the mean and spring tidal conditions. The currents inthe entrance channel required to pass the above flows depend on the areas of the cross sections and on the velocity distributions. On the basis of present channel depths it is estimated that tidal currents in the entrance channel are of the order of 0.3 knot.

40. If either the Copicut Neck beach or the Canapitsit barrier beach are allowed to breach, tidal and current conditions at Cuttyhunk Harbor would be affected.

SHORE LINE AND OFFSHORE DEPTH CHANGES

41. Comparative shore line and offshore depth changes have been compiled from maps of the U. S. Beach Erosion Board, the U. S. Coast & Geodetic Survey, and from data developed in connection with this study. The shore line and offshore depth changes are shown on Plate 5.

42. Shore lines have been developed for this study from aerial photographs of 7-19-1944, 10-9-1951, 4-24-1954, 11-15-1955 and 4-11-1962. Limited offshore contours have been developed from surveys made in connection with this study on November 20-29 and December 3-4, 1962. These surveys are shown on Plates 2 and 3.

43. The shore line change maps indicate that erosion of the shore of Cuttyhunk Island in the past 110 years has been limited, in general. Maximum erosion rates along the shore of the westerly half of the island are generly within one foot per year. At Copicut Neck erosion rates are less than 0.5 foot per year, and at Canapitsit Island erosion of its southerly shore has been in the order of one foot annually. The only area of serious change, shifting and erosion is the barrier beach which connects Cuttyhunk and Canapitsit Islands. This beach has had a history of breaching and of northward shifting or erosion of about 3 feet per year. Protective works undertaken in recent years have interfered with this natural process.

44. The only area where accretion has been experienced is the sand spit which extends southeasterly from Copicut Neck. Most of this accretion had occurred as a result of construction of the north jetty and is presently continuing at a progressively smaller rate.

45. With the exception of the offshore area in the vicinity of the Canapitsit barrier beach, there is only one survey interval available for the offshore depth changes around Cuttyhunk Island. The area generally south of the island is covered by a 42-year interval, and the area to the north by a 51-year survey interval. The changes of the 6-, 12- and 18-foot depth contours all show fluctuations between areas of erosion and accretion, and in most cases indicate similar areas of a predominant change. This signifies erosion or accretion, as the case may be, of the entire offshore beach slope. However, changes in the offshore depth contours do not appear to be directly related to changes of the shore line.

46. The area south of Nashawena Island has shoaled up to about 3 to 4 feet annually in the interval 1845-1887. On the south side of Canapitsit Channel there appears to be a limited scour of about 1 foot per year. Along the south shore of Canapitsit Island the 6-foot depth contour has fluctuated with both the erosion and the accretion rates of the order of one foot annually. In the same area the 12-foot contour shows accretion of 1 to 2 feet and the 18-foot contour accretion of 1 to 3 feet pear year.

47. The offshore area along the south side of the Canapitsit barrier beach shows some accretion at the center flanked by general erosion to the east and to the west. Accretion at the center has amounted to rates of 2 to 4 feet annually, with the greater rate at the 18-foot depth. To the east of the center, the 6- and 12-foot contours eroded up to 8 feet per year, while the 18-foot contour had an annual rate of erosion of less than 3 feet. To the west of the center, erosion rates of 8 to 10 feet per year were experienced throughout the offshore area; most extensive at the 6-foot depth.

48. The limited data from the 1962 surveys which cover the offshore area south of the Canapitsit barrier beach indicate a continued accretion at the center for the 6-foot contour only and at a rate of less than one foot per year. Adjacent to the center the 6-foot contour has receded for limited lengths at rates of 2 to 4 feet per year. Beyond the erosion areas and from a distance of about 1,000 feet from the center there are limited areas of accretion of about 2 feet at the 6-foot depth. The 12-foot contour in 1962 follows generally the 1887 location, except in the vicinity of Canapitsit Island where it has been shoaling at about 2 feet per year. The 18-foot contour has receded up to 3 feet annually from its 1887 location over a length of about 2,000 feet. There is no change to the west therefrom and there is limited accretion of one foot per year in the vicinity of Canapitsit Island to the east.

49. The offshore area to the south of the central portion of Cuttyhunk Island shows annual erosion rates of up to 6 feet at the 6- and 12-foot depths and fluctuating changes at the 18-foot depth with rates varying up to about 2 feet per year.

50. The offshore area to the south of the West End Pond has experienced general accretion of 4 to 7 feet per year; more extensive accretion at the 18-foot depth.

51. The offshore area to the west of the West End Pond has experienced general erosion with annual rates of 3 to 14 feet.

52. North of the West End Pond the 6-foot contour receded at a rate of 2 feet per year during the period 1845-1896. In the same area the 12- and 18-foot contours receded up to 3 feet in limited extents and experienced more extensive accretion of up to 6 feet per year.

53. Northwest of the central portion of Cuttyhunk Island there was general accretion of 2 to 4 feet per year.

54. The offshore area to the north of the central portion of Cuttyhunk Island and adjacent to the Copicut Neck beach has experienced general erosion of 1 to 2 feet annually.

55. General accretion at annual rates of up to 2 to 3 feet is indicated at the offshore area along the westerly shore of Copicut Neck and off the barrier beach.

56. Along the easterly shore of Copicut Neck there has been extensive erosion of up to 6 feet annually at the 6- and 12-foot depths. However, there appears to have been substantial shoaling at the 18-foot depth with annual rates of up to 6 feet.

57. East of the Copicut Neck spit and south of Pease Ledge there was accretion of up to 2 to 3 feet annually at the 6- and 12-foot depths. North of Canapitsit Island the 6- and 12-foot contours eroded up to 3 feet per year.

58. At the north side of Canapitsit Channel there was accretion at annual rates of up to 7 and 10 feet at the 12- and 18-foot depths. Although comparative contours are not available at the 6-foot depth, it is probable that similar accretion has occurred.

59. The offshore area in the vicinity of Knox Point at the northwest tip of Nashawena Island shows some accretion of up to 4 feet annually at the 12-foot depth and more general erosion at the 12- and 18-foot depths with annual rates of up to 4 and 6 feet. Comparative contours at the 6-foot depth are not available around Knox Point. It is probable that accretion occurred on the west side and erosion on the north side of this point.

60. The significance of the shore line and offshore depth changes in the study area is generally expected to have limited impact upon the proposed structures. The natural processes of erosion and accretion around the island would continue in the future, but at progressively smaller rates as erosion of the bluffs uncovers additional boulders which would naturally resist further erosion of the shore.

MATERIALS

61. Cuttyhunk Island is of glacial origin, being the southwesterly end of the Elizabeth Island chain. It is probable that the barrier beaches forming the perimeter of the inner harbor are spits or tombolos formed through erosion of higher ground on Cuttyhunk Island, Copicut Neck and Canapitsit Island.

62. Materials on the island comprise of sand, gravel and some boulders. The interior of the island is reported to have materials which contain considerable fines. The shore is generally composed of small stones, gravel and boulders. It appears that littoral transport is small and is dependent on the limited availability of sand and other fine material from erosion of the bluffs. The entrance channel and the inner harbor areas have a natural bottom composed of sand and gravel with scattered boulders at various levels and in different concentrations. This natural bottom, especially in the excavated areas, is covered by a layer of fine sand and silt, as evidenced by the spoil yielded from maintenance dredging.

63. No borings, probings or material samples have been obtained in connection with the present study. Determination of the character of materials was based on visual inspections of the study area and on available past probings. The available probings cover the channel and anchorage areas extensively and other selected points. This information appears on survey maps of Cuttyhunk Harbor made since 1936, and it was not considered essential to be repeated herein.

HARBOR SHOALING

64. The natural channel between the outer and inner Cuttyhunk Harbor was a narrow shifting channel through sand flats and over a bar prior to stabilization in 1906 by dredging and construction of jetties. The Canapitsit barrier beach had, apparently, been migrating northward into the outer harbor and has been subjected to breaching. The Copicut Neck spit had been progressing southeastward toward the inlet channel and much of this growth has been arrested by the north jetty.

65. The above processes influence to varying degrees the rate of harbor shoaling. Most significant are the effects from breaching of the Canapitsit barrier beach. When this barrier is breached large quantities of material deposit in the entrance channel. Even

when the beach becomes low in places, without a regular breach, the tidal and wave action from the south causes overtopping of the barrier and carries some material into the harbor.

66. In order to evaluate the rates at which various parts of the harbor have been shoaling in the past, a detailed study was undertaken. This study included analysis of about 45 survey maps, covering 37 different hydrographic and topographic surveys since 1938. To facilitate analysis of the rates of shoaling and/or scour a set of 60 check points were assigned throughout the channel and anchorage areas as shown on Plate 9. At each of these check points soundings were recorded for every available survey and analysis was made of comparative surveys.

67. The computed rates of change were found to vary considerably. This may be attributed in part to incomplete coverage by many of the surveys, to presence of boulders, to bottom irregularities and to possible excavation or dredging accomplished in the past by other interests. In addition, the successive rates reflect the constantly changing conditions of the past. In order to estimate approximate representative rates, the values of successive rates were examined, obviously erroneous and excessive rates were discharded, and rates of reasonably expectable values were weighed in terms of the length of the individual survey interval. The estimated values for neighboring check points were then averaged and estimated shoaling rates were computed for the enclosed portion of channel or anchorage area. These shoaling rates were estimated in increments of 0.05 feet per year.

68. The volume of annual shoaling for various parts of the harbor is estimated as follows:

Turning basin in inner harbor..............	200	cubic yards
Channel between turning basin and anchorage.	100	" "
Channel along anchorage....................	150	" "
Inlet channel from anchorage to bend........	300	" "
Inlet channel from bend to south jetty......	600	" "
Entrance channel between jetties............	150	" "
Entrance channel in outer harbor............	300	" "
Northerly half of 10-foot anchorage.........	800	" "
Southerly half of 10-foot anchorage.........	600	" "
Total annual harbor shoaling volume:	3,200	cubic yards

DESIGN CONSIDERATIONS - COPICUT NECK BARRIER BEACH

69. The design tide is 6 feet above Mean Low Water. Waves in the area have been discussed previously. The generated deep water waves are refracted as they reach Copicut Neck beach. The refracted waves are as follows for the northeasterly section and the southwesterly section of the barrier beach:

	W	WNW	NW	NNW	N
H_o (feet)	7.8	5.55	4.1	3.8	3.8
T (seconds)	6.75	5.45	4.4	4.2	4.2
H_o' (feet), northeast section	6.6	5.05	3.75	3.2	2.7
southwest "	4.1	4.4	3.75	3.2	2.35
H_o'/L_o, northeast section	.0282	.0334			
southwest "	.0176	.0289			
H_o'/T^2, northeast section	.145	.171			
southwest "	.090	.148			
d_b (feet), northeast section	8.3	6.1			
southwest "	6.1	5.6			
H_b (feet), northeast section	6.5	4.75			
southwest "	4.75	4.4			

70. In the above relationships, H_b should be used to limit the magnitude of H_o'; at the northeast section H_o' is limited to 6.5 and 4.75 feet for the W and WNW directions, respectively, and the corresponding values of H_o'/T^2 are .143 and .161.

71. Run-up is dependent on the slope of the foreshore area and on the relative location of the proposed structure. Estimates of run-up for the northeast and southwest sections indicate that they may vary up to 12 and 9 feet, respectively. However, it is not considered practical to construct the proposed structure to the height which is required in order to prevent overtopping. Some limited overtopping should be tolerated without affecting the project adversely. The rate of overtopping is estimated to be roughly of the following magnitudes:

	Crest at +10 MLW		Crest at +12 MLW	
Depth at toe:	0	9'	0	9'
Rate of overtopping in cfs/ft of crest:				
Northeasterly section	0.3	2.6	0	0.5
Southwesterly section	0.1	1.0	0	0.1

On the basis of the above, a crest elevation appears to be required between 10 and 12 feet above Mean Low Water, depending on the relative location of the structure. It is considered desirable to limit overtopping to less than 1.0 cfs per foot of crest.

72. Design of the rock mound structures should be based on considerations which include certain other factors in addition to the physical design criteria. These other factors may include the difficulty of maintaining the structure in the future; the probability that small damage to the structure would have little impact on the navigation project; partial failure of the structure may contribute to some shoaling of adjacent areas of the inner harbor, but would not render the remainder of the project unusable; the trend of littoral drift appears to indicate some accumulation potential at the Copicut Neck beach, although littoral materials in the area are relatively small; the possibilities of scour at the toe and at the heel of the structure; etc.

73. For the physical design of the structure, cover stone of 165 lbs per cubic foot is assumed. The K_D values for the cap and trunk of the structure are estimated at 2.5 and 3.0, respectively, assuming rough stone in 2 layers pell-mell and subject to breaking waves in shallow water, and a side slope of 1 on 1.5. If the stone is placed in position and carefully interlocked, the respective K_D values would be 3.5 and 5.0. The design wave height for sizing stone should be H_b, despite presently shallower water at the toe of the structure, in order to provide for possible future scour. On the basis of the above criteria, the following design components are estimated:

	Southeast section		Northeast section	
	Cap	Trunk	Cap	Trunk
Stone size in tons, placed	.45	.31	1.10	.80
pell-mell	.62	.53	1.57	1.30

	Southeast section		Northeast section	
	Cap	Trunk	Cap	Trunk
Thickness of cover layer (ft)	3.5 4.0	3.0 3.7	4.7 5.3	4.3 5.0
Thickness of underlayer (ft)	1.8	1.7	2.5	2.3
Crest width for 3 stones (ft)	5.5 (use 6')		7.5 (use 8')	
Minimum structure height (ft)	5		7	
Height with 1' crushed stone base	6		8	

74. In order to protect the toe of the structure a stone apron is considered desirable. This apron can be generally 10 feet wide and 2 feet thick, preferably founded on a layer of crushed stone.

DESIGN CONSIDERATIONS - CANAPITSIT BARRIER BEACH

75. The design tide is 6 feet above Mean Low Water. Waves in the area have been discussed previously. The barrier is exposed to waves from Vineyard Sound and the Atlantic Ocean on its south side and to waves from Buzzards Bay on the easterly half of its north side. Although wave attack on the south side is most severe, the effects of waves on the north side should not be disregarded.

76. Waves generated in Buzzards Bay are refracted and have the following characteristics in the vicinity of the jetties and along the north side of the Canapitsit barrier beach:

	T (sec)	H_o	H_o'	d_b	H_b	H_b/T^2	R
Jetties:	4.5	4.4	5.7	5.7	4.5	.222	3.6
Barrier, north side:	4.5	4.3	3.2	3.9	3.0	.148	2.0

77. Waves from the southerly quadrant reaching various sections of the Canapitsit barrier beach are refracted in the approach area and in the near-shore area. The net refraction coefficients for selected wave periods and directions, applicable to general sections of the south side of the barrier beach, have been estimated to be as follows:

Direction	Period	Tide	West section	Center section	East section
S	7 sec	+6'	1.16 .58	Inf. .68	1.54 .60
		MLW	Inf. .50	Inf.	1.00
S	10 sec	+6'	.36	Inf.	.93
S	15 sec	+6'	.25	Inf.	1.19
SSW	7 sec	+6'	.52	1.38	.68 .74
		MLW	.62 .33	Inf.	.35
SSW	10 sec	+6'	1.15 .40	Inf.	.49 Inf.
SSW	15 sec	+6'	.29	Inf.	.41 .71
SW	7 sec	+6'	.29	.42 .36	.56
		MLW	.27	.47 .36	.78
SW	10 sec	+6'	.35	.45 .43	.72

78. Analysis of the above refraction coefficients, as they may affect deep water wave statistics shown on Plate 7, shows the following wave heights applicable to sections of the barrier:

	Tide	Period	West section	Center section	East section
Max. H_o'	+6'	7 sec	16' 6' 8'	Inf. 17' 10'	22' 9'
	MLW	7 sec	Inf. 3' 7'	6' Inf. 4'	14'
Max. H_o'	+6'	10 sec	23' 7' 8'	9' Inf. 9'	10' 14' Inf.
Max. H_o'	+6'	15 sec	4'	Inf.	6' 17' 10'
Max. H_o'	+6'	All	23' 7' 8'	Inf. Inf. 10'	22' 17' Inf.
Max. d_b	+6'	7 sec	16' 8' 10'	Inf. 16' 11'	19' 11'
Max. d_b	+6'	10 sec	25' 11' 13'	14' Inf. 14'	14' 18' Inf.
Max. d_b	+6'	15 sec	10'	Inf.	13' 27' 19'
Max. d_b	+6'	All	25' 11' 13'	Inf. Inf. 14'	19' 27' Inf.
Max. H_b	+6'	All	20' 9' 10'	Inf. Inf. 11'	15' 21' Inf.

In the above values the word "Inf." signifies that there is an unlimited potential and, therefore, wave heights are limited only by existing depths, or by depths that could be reasonably expected to occur in the future as a result of scour. These existing and anticipated depths would also limit and control waves for which specific values have been indicated above.

79. An analysis has also been made of locally generated waves by storms occuring in the area. The deep water characteristics of these waves have been discussed previously. The refracted characteristics are estimated to be as follows:

	West section			Center section			East section		
H_o' (for H_o=8.3';t=+6') T =7.1"	9.6'		4.8'	Inf.	5.6'		12.8'		5.0'
H_o' (for H_o=8.5'; ") T =7.2"		4.4'			11.7'		5.8'		6.3'
H_o' (for H_o=13.3'; ")		4.7'		6.0'	5.7'			9.6'	
d_b (for all above)	11.1'	8.5'	7.0'	Inf.	12.8'	9.6'	13.5'	13.6'	8.4'
H_b (")	8.7'	6.6'	5.5'	Inf.	10.0'	7.5'	10.5'	10.6'	6.6'

80. As most of the south side of the Canapitsit barrier beach is generally subject to wave magnitudes greater than can be supported without breaking at the existing and prospective depths, further analysis has been made of breaking waves at selected depths. Some of the characteristics of breaking waves at rip rap structures and estimates of run-up and overtopping are listed below:

d_b (feet)	3	6	9	12	15	18	21	24
H_b (feet)	2.34	4.69	7.03	9.4	11.7	14.1	16.4	18.8
T (seconds);(for $H_o'=H_b$)	4.0	5.7	7.1	8.2	9.2	10.0	10.8	11.5
Est. run-up above tide	4.4'	9'	13.5'	18'	23'	27'	32'	36'

Crest above tide for rate of overtopping of:

1 cfs/ft or less	1'	2'	6'	10'	(14)	(16)	(19)	(24)
2 " "		1'	4'	7'	(11)	(13)	(15)	(20)
3 " "			3'	6'	(10)	(12)	(14)	(18)

81. The behavior of offshore breakwaters in dissipating a portion of the energy of oncoming waves during conditions of submergence has been analyzed for consideration in the design of plans

with twin breakwaters. The seaward wave height (H_s) is taken to be equal to the maximum wave height (H_b) that can be supported by the natural depths (d_b) at the structure without breaking, or at the point of breaking. The wave height which continues towards shore after passing over the offshore breakwater is designated as H_L. Similarly, the seaward and landward wave energies are designated by E_s and E_L, respectively. The ratio E_L/E_s represents the portion of the energy which is not dissipated by the offshore breakwater. This relative residual energy is dependent on the relative submergence of the structure (d/Z). If the twin breakwaters are spaced closely together it may be desirable to divide the energy equally, $E_L/E_s=0.50$, which would correspond to $d/Z=1.18$ and $H_L/H_s=0.69$. If the twin breakwaters are spaced sufficiently apart so that some energy dissipation could be realized in the area between them, it may be more appropriate to increase the relative residual energy. Assuming that 20% of the wave energy could be dissipated in the area between the breakwaters, then the offshore breakwater should be designed for $E_L/E_s=0.60$; $d/Z=1.30$ and $H_L/H_s=0.76$. However, as it is desirable to maintain uniform crest elevations, further analysis indicates the following estimated relative wave heights and residual energies and other wave characteristics for selected crest elevations and depths:

<u>Crest Elevation +6.0' above M.L.W.</u>; $Z=d$; $d/Z=1.00$; $E_L/E_s=0.25$;

d (feet)	3	6	9	12	15	18	21	24
H_L (for $H_L/H_s=0.50$)	1.17	2.35	3.52	4.7	5.86	7.05	8.2	9.4

<u>Crest Elevation =3.0' above M.L.W.</u>; $Z=d-3$;

d (feet)	3	6	9	12	15	18	21	24
d/z	Inf.	2.0	1.5	1.33	1.25	1.2	1.17	1.14
E_L/E_s	1.00	(.8)	.70	.62	.56	.52	.48	.45
H_L/H_s	1.00	(.82)	.78	.77	.74	.72	.68	.66
H_L (feet)	2.34	3.85	5.5	7.2	8.7	10.1	11.2	12.4

<u>Crest Elevation at M.L.W.</u>; $Z=d-6$;

d (feet)	6	9	12	15	18	21	24
d/Z	Inf.	3.0	2.0	1.67	1.5	1.4	1.33
E_L/E_s	1.00	(.90)	(.80)	(.75)	.70	.66	.62
H_L/H_s	1.00	(.85)	(.82)	(.80)	.78	.78	.77
H_L (feet)	4.7	6.0	7.7	9.4	11.0	12.8	14.4

82. In addition to the above, there should be given consideration to diffraction of waves off the tips of the offshore breakwaters. Although the pattern of diffraction is dependent generally on the wave length and on the relative gap opening, in the present case the relative submergence of the structure is expected to influence the degree of diffraction. A method to account for structure submergence in the determination of diffraction consists of the following procedure: For a specific relative submergence establish the relative residual wave energy. From this obtain the relative loss of energy and determine the relative equivalent wave height corresponding to the loss of energy. Adjust the diffraction coefficients (K') by the formula $K'_{es} = 1 + (K' - 1)\ (H_{es}/H_s)$ where the subscripts "es" signify equivalent for submerged structure. With greater submergence the degree of diffraction would be reduced and K'_{es} will approach 1.00. In general, however, since in most areas the maximum supportable wave heights are estimated to exist, diffraction would be relatively insignificant.

83. In designing offshore breakwaters it is often desirable to raise the crest so that it would be visible most of the time, if not all the time. However, in the present case no navigation is expected in the vicinity of the offshore breakwater and the importance of this factor is considered to be secondary. Low offshore breakwaters could be constructed with their tips raised to visible levels, thus designating the breakwater location. Heavier sections at the tips of detached offshore breakwaters are generally desirable for protection of the structure.

84. Potential future erosion or scour of the natural bottom at proposed structures has also been given consideration. The degree of such erosion is not easily determined. Plate 4 shows the past fluctuation of profiles across the barrier beach and in the offshore area. The lower limit of this fluctuation may serve to indicate the top of the natural relatively compact bottom; as most of the overlying material was placed artificially, erosion may be possible to this lower limit. A rule-of-thumb method suggests that the maximum depth of scour trough below the natural bed at the toe of a structure, may be approximated as being equal to the height of the maximum unbroken wave that can be supported by the original depth of water. It appears appropriate that, for submerged structures, the maximum equivalent wave corresponding to the energy loss at the structure should be utilized. On the basis of the above, the maximum depth of scour trough would be estimated by the following formulae:

High structures: depth of scour trough = 0.78d

Submerged structures: " " " " = 0.674Z

85. In order to control scour at the toe of structures, it is suggested that aprons of stone be considered. A stone apron would automatically adjust to the scour of the bottom and prevent undermining of the structure. The width of apron required in order to prevent all scour is probably dependent on the wave length and height of the breaking wave. It is considered that limited scour could be tolerated without serious consequences. In this respect it is suggested that the apron width be equal to at least once, and preferably twice, the maximum potential depth of scour trough. One layer of armor stone would generally be sufficient for the construction of aprons in this project. In addition, it would be desirable to place the armor stone on a crushed stone base layer.

86. In the design of single dikes to be constructed on top of the barrier beach, aprons should be designed on the basis of either the potential maximum depth of scour trough determined by 0.78d, or the lowest past profile, whichever is greater. On the north side of all structures at the barrier beach the maximum depth of scour trough should be based solely on the maximum waves from Buzzards Bay, as limited by available depths.

87. The physical design of rip-rap structures in the area should incorporate such other design considerations as the difficulty of maintaining offshore structures in the future; some damage to an offshore structure could be tolerated without seriously affecting the project; damage to a structure located on the barrier may cause encroachment upon the navigation channel; limited damages of a structure located on the barrier can be repaired with little difficulty; damage to the jetties can affect the entrance channel and impair navigation; maintenance of the jetties does not present any unusual difficulties; material from maintenance or new dredging in the harbor which may be spoiled on the south side of the barrier would be most valuable to the dike on the barrier; similarly, littoral drift from the south side of the island would tend to accrete along the barrier; the single breakwater, or the onshore dike of the twin breakwaters, should be constructed relatively sand-tight, in order to prevent the natural trend for northward movement of material at the barrier; the old car floats and barges, which had been placed in the past, in order to preserve the barrier, should be accounted for and incorporated in the proposed protection works; the south jetty should preferably, but not necessarily, be connected to any dike proposed to be constructed on the barrier, north of the series of old car floats; etc.

88. For the design of repairs to the south jetty, a crest elevation of +7.0 feet above M.L.W. is considered adequate for navigation. Assuming the trunk stone to be pell-mell and the cap stone placed, the corresponding K_D values are 3.0 and 3.5. For the design wave of 4.5 feet, the required stone sizes are 0.45 and 0.38 ton, respectively; based on side slopes of 1 on 1.5. A crest width of 5 feet will permit 3 stones of the required size. Along the north side of the barrier, the cap would not be affected by northerly waves for elevations higher than +8.0 feet. The trunk of placed stone with a K_D of 5.0 and side slope of 1 on 1.5 requires stone weighing 0.08 ton. This criterion may also be applied for the shore connection of the south jetty.

89. Single massive breakwaters and the onshore dike of the twin breakwater system should be constructed generally pell-mell below Mean Low Water, or +3.0 feet above M.L.W., and above that elevation the armor stone should be carefully placed to obtain better interlocking. Stone subject to breaking waves in shallow water would have K_D values of 2.5 and 3.0 for pell-mell construction of cap and trunk, the values of 3.5 and 5.0 for placed stone at the cap and trunk, respectively. Offshore breakwaters should be regarded to be constructed solely pell-mell, although every effort should be exercised during construction to fit individual stones. Side slopes should be generally 1 on 1.5, except where excessive stone sizes are required. In order to limit the size of stone a flatter side slope should be specified in certain cases. Stone for the construction of aprons should be similar to stone for the trunk.

90. The required stone sizes in tons for various depths of water at the single breakwater, or at the onshore dike of the twin breakwater system, are listed below. In addition, there are listed the required stone sizes for a submerged offshore breakwater:

Breakwater with crest higher than El. +6.0' above M.L.W.

d_b	3	6	9	12	15	18	21	24
$H_b = 0.78d_b$	2.34	4.69	7.03	9.4	11.7	14.1	16.4	18.8
Pell-mell, cap K_D=2.5	.07	.58	1.94	4.64	8.95	15.7	24.7	37.1
" ,trunk K_D=3.0	.06	.48	1.62	3.87	7.46	13.1	20.6	31.0
Placed, cap K_D=3.5	.05	.41	1.39	3.31	6.40	11.2	17.6	26.5
" , trunk K_D=5.0	.04	.29	.97	2.32	4.48	7.8	12.3	18.6
Side slope for maximum stone size at 15 tons; cot a:								
K_D: 2.5						1.6	2.5	3.7
3.0							2.1	3.1
3.5							1.8	2.7
5.0								1.9

Breakwater with crest lower than El. +6.0' above M.L.W.

Structure height, Z	3	6	9	12	15	18	21	24
H_{es} = 0.675Z	2.02	4.05	6.08	8.1	10.1	12.2	14.2	16.2
Pell-mell, cap K_D: 2.5	.05	.37	1.25	2.97	5.82	10.0	16.0	23.3
" , trunk K_D: 3.0	.04	.31	1.04	2.48	4.85	8.35	13.3	19.4
Side slope for maximum stone size at 15 tons; cot a:								
K_D: 2.5							1.6	2.4
3.0								2.0

91. The width of crest required in order to accomodate 3 cap stones and the thickness of armor for 2 layers of cover stone are listed below. In addition, the required thickness of underlayer, composed of stones of 1/10th size, is indicated:

Crest Width	Thickness of Armor	Underlayer	Cover stone Weight, tons
3'	2'	1'	.1
5'	3.5'	1.5'	.4
6'	4'	2'	.7
8'	5.5'	2.5'	1.5
10'	6.5'	3'	3.0
12'	8'	3.5'	5.0
15'	10'	4.5'	10.0
17'	11.5'	5.5'	15.0
20'	13.5'	6'	25.0

92. On the basis of the above design considerations, the following general dimensions and stone sizes were used for the comparative study of the selected alternatives. All plans included repairs to the south jetty and shoreward extension, with 5-foot wide crest at El. +7.0' and 1 on 1.5 side slopes. In addition, all plans included a stone mound with apron at the Copicut Neck Beach.

	Plan I	Plan II	Plan III	Plan IV
Length of Canapitsit structure:				
a. Onshore	2600'		2600'	2600'
b. Nearshore		2500'	1900'	
c. Offshore				1400'

	Plan I	Plan II	Plan III	Plan IV
Crest elevation:				
a. Onshore; east	+12		+8	+8
west	+10		+7	+7
b. Nearshore; east		+15	+4	
west		+12	+3	
c. Offshore; east				+2
west				+0
Crest width:				
a. Onshore; east	6'		4'	4'
west	5'		3'	3'
b. Nearshore; east		12'	10'	
west		10'	8'	
c. Offshore; east				10'
west				8'
Width of apron:				
a. Onshore; east	10'		0	0
west	0		0	0
b. Nearshore; east		20'	10'	
west		20'	5'	
c. Offshore; east				10'
west				8'
Weight of cover stone (tons):				
a. Onshore; east	0.4		0.1	0.1
west	0.1		0.1	0.1
b. Nearshore; east		8	4	
west		5	2	
c. Offshore; east				4
west				1

QUANTITIES AND COSTS

93. Stone quantities are based on specific heights of structure, which may require excavation below existing grades and backfilling. Stone for pell-mell construction and aprons was estimated at 1.5 tons per cubic yard. Stone to be fitted and placed was estimated at 1.65 tons per cubic yard. Contingencies have been based on 12% of the construction cost. Unit costs are based on

prevailing 1963 prices and on analysis of the construction procedures applicable to Cuttyhunk Harbor, Mass. Interest and amortization charges have been based on an interest rate of 2.875% for 50 years.

94. Maintenance requirements are based on average annual rates of shoaling of the harbor, as discussed previously in this Appendix, which may be expected to prevail in the future. Maintenance requirements for the proposed riprap structures are difficult to determine, and, therefore, estimates of probable rates have been included.

95. The estimated quantities, costs and annual charges for the alternative plans considered are presented below:

	Plan I	Plan II	Plan III	Plan IV
Copicut Neck Beach:	(ALL PLANS)			
First cost of construction				
Stone, 8500 tons at $12	$102,000			
Contingencies	12,000			
Engineering and Design	2,000			
Supervision and Administration	9,000			
Total First Cost	$125,000			
Annual charges				
Interest	$ 3,600			
Amortization	1,150			
Maintenance	250			
Total Annual Charges	$ 5,000			
South Jetty Repairs and Extension:	(ALL PLANS)			
First cost of construction				
Stone, 2500 tons at $12	$ 30,000			
Contingencies	3,600			
Engineering and Design	1,200			
Supervision and Administration	3,200			
Total First Cost	$ 38,000			
Annual charges				
Interest	$ 1,050			
Amortization	350			
Maintenance	600			
Total Annual Charges	$ 2,000			

Channel and Anchorage at Cuttyhunk Harbor: (A L L P L A N S)

First cost of construction

None

Annual charges

Maintenance $ 4,000

	Plan I	Plan II	Plan III	Plan IV
Canapitsit Barrier Beach:				
First cost of construction				
Stone quantity				
onshore	27,000t		5,000t	5,000t
nearshore		100,000t	25,000t	
offshore				20,000t
Stone price				
onshore	$14		$14	$14
nearshore		$15	$16	
offshore				$16
Excavation & backfill	20,000 cy	2,000 cy	4,000 cy	4,000 cy
Stone cost	$378,000	$1,500,000	$470,000	$390,000
Excavation cost	30,000	3,000	6,000	6,000
Contingencies	49,000	180,000	57,000	47,500
Engineering & Design	10,000	27,000	12,000	11,500
Supervision - Administration	38,000	90,000	45,000	40,000
Total First Cost	$505,000	$1,800,000	$590,000	$495,000
Annual charges				
Interest	$ 14,500	$ 51,800	$ 17,000	$ 14,200
Amortization	4,700	16,600	5,400	4,600
Maintenance est.	4,800	16,600	6,600	5,200
Total Annual Charges	$ 24,000	$ 85,000	$ 29,000	$ 24,000
ENTIRE PROJECT TOTALS				
First Cost of Construction	$668,000	$1,963,000	$753,000	$658,000
Annual Charges	$ 35,000	$ 96,000	$ 40,000	$ 35,000

CONCLUSION

96. The problems, shore processes, tidal and wave action, affecting the Cuttyhunk Harbor area, have been studied in detail and are discussed in the appropriate sections above. Economic studies have shown that Plans I and IV are equally the most economical plans. Of these two, Plan IV lends itself to construction in phases; the onshore stone dike could be constructed first to prevent the imminent breaching of the Canapitsit barrier beach; the easterly offshore breakwater could be undertaken next to give further protection to the most vulnerable area; and the westerly offshore breakwater could be undertaken last in order to complete the desired protection of the barrier. However, Plan I could also be phased by constructing first the section in the critical area and later extending to the desired limits, and has the advantage of being above water where construction and maintenance surveys can be easily made. Another method of staging Plan I consists of constructing the dike on the existing beach without any extensive excavation; later, additional stone would be placed, as and when required, in the form of increased maintenance.

After careful evaluation of all factors affecting the project, it is considered that Plan I should be adopted as the simplest, most feasible and economical project solution.